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5. ENVIRONMENTAL BASELINE

Section 7 of the ESA defines the environmental baseline as "the past and present impacts of all federal, state, or private actions and other human activities in the action area." The environmental baseline encompasses the historic and present conditions, as well as the progression of these conditions from the past to the present (Smith 1999b). This chapter describes the corresponding environmental baseline for the Willamette Project and provides context for evaluating the effects of the project on listed species that are found within the project area. Information is presented when available that describes the environmental conditions of the aquatic and terrestrial ecosystem both prior to the construction of the 13 USACE Willamette dams, and under current operating conditions.

The Willamette River basin is located between the Cascade and Coast Mountain ranges in the northwest part of Oregon (Figure 1-1). The basin drains an area of 11,478 square miles and annual runoff averages about 24 million acre-feet. It is bounded by the Cascade Range to the east, the Calapooya Mountains to the south, the Coast Range to the west, and the Columbia River to the north. The Willamette Valley is a broad, elongated lowland that is oriented north-south. The mountains of the Coast Range are characterized by highly dissected, low relief topography, with elevations reaching 4,000 feet above Mean Sea Level (MSL). The Cascade Range mountains have a different and more complex topography, where low foothills quickly give way to steep mountain slopes interspersed with volcanic cones, including five peaks that attain elevations of more than 10,000 feet MSL. Peak heights of these ranges average about 5,000 and 2,000 feet, respectively. The Calapooya Mountains connect the two principal ranges. The interlying Willamette Valley is filled with alluvial sediments that originated on the adjacent mountain slopes. Valley elevations range from sea level near the Columbia River to 450 feet in Eugene, Oregon near the head of the Willamette Valley, 120 miles to the south. The valley floor, as much as 30 miles wide and covering approximately 3,500 square miles, is level in many places, gently rolling in others, and broken by several groups of hills and scattered buttes.

The climate is characterized by cool wet winters and warm dry summers. About 70 to 80 percent of the annual precipitation falls from October through March, and less than 5 percent falls in July and August (Wentz et al. 1998). In the Cascades, most precipitation falls as snow above approximately 5,000 feet MSL; however, the Coast Range and Willamette Valley receive relatively little snow (Wentz et al. 1998).

Major tributaries, including the Middle Fork Willamette River, McKenzie River, Santiam River, Molalla River, and Clackamas River rise in the Cascade Range and enter the river from the east. The east side tributaries have relatively steep gradients and high base flows sustained by melting snow. In contrast, west side tributaries, such as the Long Tom River, Marys River, Luckiamute River, Yamhill River, and Tualatin River head in the lower elevation Coast Range mountains. The upper reaches of these streams are steep, but they quickly flatten upon reaching the valley floor, taking on a meandering channel pattern. Baseflows during the summer months are relatively lower than in streams draining the opposite side of the valley, because the Coast Range mountains do not typically support a seasonal snowpack.

The Willamette River basin is home to about two-thirds of Oregon's human population, and contains the state's three largest cities (Portland, Eugene, and Salem). Water supplies have been developed for municipal, industrial, domestic, and agricultural use. The Willamette River has been navigable for commercial barges for more than 100 miles upstream from its mouth. However, the authorized navigation channel up to Corvallis is no longer maintained.

The Willamette River system contains approximately 61 fish species, although nearly half of these species were introduced through human activity (i.e., non-native; Altman et al. 1997). The number and composition of species varies throughout the system. In general, the low elevation, low gradient, warm water mainstem channels contain the largest number of species with fewer species found in the higher gradient and colder headwater reaches. Relative to the seven other ecoregions in Oregon, the Willamette Valley system generally contains the greatest fish species richness and diversity, the most introduced species, and the fewest salmonid species (Whittier et al. 1988, cited in Altman et al. 1997).

Information on current fish habitat conditions within the mainstem Willamette River and its subbasins is contained in a series of subbasin plans developed by the ODFW for the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (ODFW 1990a). Additional information on aquatic habitat conditions is available through ODFW's Aquatic Inventories Project (ODFW 1997a), ODEQ's 303(d) listings (ODEQ 1998), Altman et al. (1997), and several reports prepared by the USFS, Willamette National Forest (Skeesick et al. 1988; USFS 1994; Unthank 1998).

Information is limited regarding historical habitat conditions in the Willamette River basin. Some information is available that describes mainstem and tributary habitat conditions during the 1930s and 1940s (Parkhurst et al. 1950; McIntosh et al. 1995). These reports represent the earliest and most comprehensive documentation available on the condition and extent of anadromous and resident fish habitat prior to most hydropower development (Altman et al. 1997). However, although the surveys were completed prior to the construction of many of the USACE dams on the Willamette system, the habitat and fisheries resources in the Willamette River basin had already been severely impacted by land development, water diversion, pollution, hatchery operations, and overharvest. Little to no data exist on pre-settlement fish habitat. Fish habitat was surveyed again throughout much of the basin by the Fish Commission of Oregon (Willis et al. 1960) in the late 1950s following construction of most of the USACE dams. Fulton (1968, 1970) compiled much of that and other information. Many of these sources of information were used to prepare this section on the varying baseline environmental conditions influencing fish populations in the Willamette system.

The following sections describe general environmental and habitat conditions, and listed, candidate, or related species distributions in the mainstem Willamette River and in each of the subbasins containing Willamette Project facilities. Table 5-1 lists fish species that are found throughout the Willamette River basin. Detailed descriptions of listed population status and species life histories are provided in Chapter 4.

5.1 MAINSTEM WILLAMETTE RIVER

The Willamette River flows northward from the confluence of the Coast Fork and Middle Fork Willamette rivers for 187 miles before joining with the Columbia River. It enters the Columbia River at RM 101.5. The stream gradient is relatively gentle, averaging 2.8 feet per mile (<0.05%) from RM 187 to RM 52, and averaging 0.12 feet per mile (0.002%) from RM 52 to Willamette Falls at RM 26.5. The average gradient is less than 0.10 feet per mile below Willamette Falls, where the river is subject to tidal influence (ODFW 1990b). The largest tributaries rise in the Cascade Range and drain from the east; numerous smaller tributaries rise in the Coast Range and drain from the west.

Historically, flows were naturally low in the mainstem Willamette River during the summer months and prevented passage of selected anadromous stocks past Willamette Falls. Winter steelhead, spring chinook, and Pacific lamprey were the only fish species that historically could migrate upstream above Willamette Falls. It is unknown whether sea-run cutthroat could migrate above the falls during high flows, but it is suspected that the upper Willamette River has probably never supported a substantial anadromous population of that species. The primary life-history form of cutthroat trout above Willamette Falls appears to be the resident freshwater type, which appears to be relatively rare below the falls (Orlay et al. 1999). No information exists

Table 5-1. Current or recent distribution of fish species in major rivers of the Willamette Project, Oregon (modified from Altman et al. 1997).

			Major Subbasins in the Willamette River Basin					
Species	**Scientific Name**	**Origin**	**C.F. Willa-mette**	**Long Tom**	**Mc-Kenzie**	**M.F. Willa-mette**	**San-tiam**	**Mainstem Willamette**
Bullhead Catfishes	**Ictaluridae**							
Black bullhead	*Ameiurus melas*	Introduced						X
Brown bullhead	*Ameiurus nebulosus*	Introduced	X	X	X	X	X	X
Yellow bullhead	*Ameiurus natalis*	Introduced	X	X			X	X
Channel catfish	*Ictalurus punctatus*	Introduced		X				X
Flounders	**Pleuronectidae**							
Starry flounder[1]	*Platichthys stellatus*	Native						X
Herrings	**Clupeidae**							
American shad[2]	*Alosa sapidissima*	Introduced						X
Lampreys	**Petromyzontidae**							
Western brook lamprey	*Lampetra richardsoni*	Native		X	X	X		X
Pacific lamprey[2]	*Lampetra tridentata*	Native		X	X	X	X	X
River lamprey[2]	*Lampetra ayresi*	Native			X			X
Livebearers	**Poeciliidae**							
Mosquitofish	*Gambusia affinis*	Introduced		X	X	X	X	
Minnows	**Cyprinidae**							
Chiselmouth	*Acrocheilus alutaceus*	Native	X	X	X	X	X	X
Common carp	*Cyprinus carpio*	Introduced		X	X	X		X
Oregon chub	*Oregonichthys crameri*	Native				X	X	
Peamouth	*Mylocheilus caurinus*	Native	X	X	X	X	X	X
Northern pikeminnow	*Ptychocheilus oregonensis*	Native	X	X	X	X	X	X
Goldfish	*Carassius auratus*	Introduced						X

Table 5-1. Current or recent distribution of fish species in major rivers of the Willamette Project, Oregon (modified from Altman et al. 1997).

			Major Subbasins in the Willamette River Basin					
Species	**Scientific Name**	**Origin**	**C.F. Willa-mette**	**Long Tom**	**Mc-Kenzie**	**M.F. Willa-mette**	**San-tiam**	**Mainstem Willamette**
Longnose dace	*Rhinichthys cataractae*	Native	X	X		X	X	X
Leopard dace	*Rhinichthys falcatus*	Native	X	X		X	X	X
Speckled dace	*Rhinichthys osculus*	Native	X		X	X	X	X
Redside shiner	*Richardsonius balteatus*	Native	X	X	X	X	X	X
Tench	*Tinca tinca*	Introduced						X
Perches	**Percidae**							
Yellow perch	*Perca flavescens*	Introduced						X
Walleye	*Stizostedion vitreum*	Introduced				X		X
Sculpins	**Cottidae**							
Prickly sculpin	*Cottus asper*	Native		X	X		X	X
Mottled sculpin	*Cottus bairdi*	Native			X	X	X	
Paiute sculpin	*Cottus beldingi*	Native	X	X	X	X	X	X
Shorthead sculpin	*Cottus confuscus*	Native			X	X	X	
Reticulate sculpin	*Cottus perplexus*	Native	X	X	X	X	X	X
Torrent sculpin	*Cottus rhotherus*	Native	X	X	X	X	X	X
Riffle sculpin	*Cottus gulosus*	Native						X
Smelts	**Osmeridae**							
Eulachon	*Thaleichthys pacificus*	Native						X
Sticklebacks	**Gasterosteidae**							
Threespine stickleback	*Gasterosteus aculeatus*	Native			X	X	X	X
Sturgeons	**Acipenseridae**							
White sturgeon	*Acipenser transmontanus*	Native			X	X		X

Table 5-1. Current or recent distribution of fish species in major rivers of the Willamette Project, Oregon (modified from Altman et al. 1997).

			Major Subbasins in the Willamette River Basin					
Species	**Scientific Name**	**Origin**	**C.F. Willa-mette**	**Long Tom**	**Mc-Kenzie**	**M.F. Willa-mette**	**San-tiam**	**Mainstem Willamette**
Suckers	**Catostomidae**							
Largescale sucker	*Catostomus macrocheilus*	Native	X	X	X	X	X	X
Mountain sucker	*Catostomus platyrhynchus*	Native	X	X	X	X	X	X
Sunfishes	**Centrarchidae**							
Pumpkinseed	*Lepomis gibbosus*	Introduced		X			X	X
Warmouth	*Lepomis gulosus*	Introduced		X			X	X
Bluegill	*Lepomis macrochirus*	Introduced	X	X	X	X	X	X
Redear sunfish	*Lepomis microlophus*	Introduced						X
Smallmouth bass	*Micropterus dolomieui*	Introduced				X	X	X
Largemouth bass	*Micropterus salmoides*	Introduced	X	X	X	X	X	X
White crappie	*Pomoxis annularis*	Introduced		X	X	X	X	X
Black crappie	*Pomoxis nigromaculatus*	Introduced		X		X	X	X
Topminnows	**Fundulidae**							
Banded killifish	*Fundulus diaphanus*	Introduced						X
Trout and Salmon	**Salmonidae**							
Coho salmon[2]	*Oncorhynchus kisutch*	Native[3]			X[4]		X	X
Sockeye salmon[2]	*Oncorhynchus nerka*	Introduced					X	X
Kokanee salmon	*Oncorhynchus nerka*	Introduced					X	
Spring chinook salmon[2]	*Oncorhynchus tshawytscha*	Native			X	X	X	X
Fall chinook salmon[2]	*Oncorhynchus tshawytscha*	Native[3]	X[4]		X	X	X	X
Mountain whitefish	*Prosopium williamsoni*	Native		X	X	X	X	X
Coastal cutthroat trout[(2)]	*Oncorhynchus clarki clarki*	Native	X	X	X	X	X	X
Summer steelhead[2]	*Oncorhynchus mykiss*	Native[3]			X	X	X	X

Table 5-1. Current or recent distribution of fish species in major rivers of the Willamette Project, Oregon (modified from Altman et al. 1997).

			Major Subbasins in the Willamette River Basin					
Species	**Scientific Name**	**Origin**	**C.F. Willa-mette**	**Long Tom**	**Mc-Kenzie**	**M.F. Willa-mette**	**San-tiam**	**Mainstem Willamette**
Winter steelhead[2]	*Oncorhynchus mykiss*	Native	X[4]	X[5]	X[4]	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	Native	X		X	X	X	X
Brook trout	*Salvelinus fontinalis*	Introduced	X		X	X	X	
Bull trout	*Salvelinus confluentus*	Native			X	X		
Trout-Perches	**Percopsidae**							
Sand roller	*Percopsis transmontana*	Native	X	X	X	X	X	X

[1] Marine species.
[2] Anadromous species; (2) includes resident form.
[3] This species was introduced upstream of Willamette Falls.
[4] Rare; only a small population exists.
[5] Rearing of fish originating from other subbasins.

whether bull trout historically migrated past the falls. Fish passage improvements at the falls, increased summer flows, and hatchery operations have led to the introduction of several other anadromous species to the upper Willamette River basin. Flows in the mainstem Willamette River are presently regulated by the 13 USACE dams located on tributary systems. The impoundment projects are regulated to reduce flooding in the winter and increase flows in the summer.

Aquatic habitat conditions in the mainstem Willamette River have been altered substantially by European settlement. Historically, the floodplain of the mainstem Willamette River was covered by dense forest that extended approximately 1 to 2 miles on either side of the river (Sedell and Froggatt 1984). The mainstem Willamette River was a meandering, braided stream with many side channels and sloughs (ODFW 1990b). Flooding was a nearly annual event during the wet winter months. In 1854, the 15.6 mile distance between Harrisburg and the McKenzie River had over 156 miles of shoreline, which has been reduced today to less than 40 miles (Sedell and Froggatt 1984). This reduction of natural shoreline length has been exacerbated by construction of stone revetments; presently about 11 percent of the Willamette River shoreline has been rip-rapped (Altman et al. 1997). In the reach of the Willamette River that flows past Portland, the shoreline has been altered significantly by waterfront development and the construction of structures built to receive and service large commercial vessels (Ward 1992). As much as 75 percent of the original shoreline of the mainstem Willamette River has been lost as the original complex of marshes, multiple channels, and oxbow lakes were eliminated by channelization and other physical changes (Sedell and Froggatt 1984). Alteration of the shoreline substrates, shoreline gradient, and water velocity has resulted in fish habitat changes and losses, and alteration of the fish community assemblages found within the river (ODFW 1990b; Altman et al. 1997). Fish assemblages at stone revetments on the Willamette River downstream of Salem are characterized by lower species richness and diversity than at natural banks, but higher densities of smaller fish (Hjort et al. 1984, cited in Altman et al. 1997). Higher densities of macroinvertebrates were found at revetments than at natural banks, and the fish positively associated with revetments are likely attracted by the high densities of invertebrate prey (Altman et al. 1997).

Conversion of the riparian areas to agricultural use has drastically altered riparian vegetation along the mainstem, which has accelerated bank and channel erosion and sedimentation of river substrates (ODFW 1990b). Logging in the upper reaches of the tributaries has also influenced water quality in the mainstem by increasing input rates of fine sediments. The removal of woody debris from the mainstem to improve the channel for navigation, combined with the fragmentation or elimination of riparian forests that could provide inputs of large woody debris (LWD), has reduced channel and habitat complexity in the mainstem (Altman et al. 1997).

Agriculture is the predominant, current land use along the mainstem Willamette. Approximately 1.4 million acres of the Willamette River basin are used for crop production and about 25 percent of this acreage is irrigated. Rangeland accounts for only a small portion of the lands adjacent to the mainstem, with most being located along the mainstem tributaries (ODFW 1990b). The effects of water withdrawals for irrigation are aggravated by agricultural practices that influence erosion, sedimentation and water quality (Altman et al. 1997).

Extensive sand and gravel mining has occurred in and adjacent to the Willamette mainstem. Aggregate mining within the bed and banks of the river is restricted to bar scalping, except for some dredging that is permitted at the Newberg Pool area (Johnson 1999).

5.1.1 Hydrology

Streamflow in the Willamette River basin reflects the seasonal distribution of precipitation, with 60 to 80 percent of the runoff occurring from October through March (Figure 5-1), and less than 10 percent occurring during July and August. Floods occur nearly every year in some part of the basin with, flooding typically occurring during a period from the middle of November through early February. Floods result principally from rainfall, augmented by snowmelt.

The USACE Willamette River Basin Project (WRBP) controls runoff from 27 percent of the watershed. Flood flows greater than 200,000 cfs were not uncommon at Albany, Oregon, prior to construction of the 13 reservoirs that make up the Willamette Reservoir System. The largest flow ever recorded at the Albany gage was 266,000 cfs on January 14, 1881, and larger unrecorded floods occurred in 1861 and 1890. Between 1895 and 1941 the average annual maximum flow rate at Albany was over 106,000 cfs, and floods were "flashy," building rapidly to the peak flow rate (USACE 1980). Since completion of the existing USACE flood control projects, the average annual maximum flow has been approximately 69,000 cfs (Figure 5-2). Operation of the project has decreased the magnitude and frequency of extreme high flow events, and has increased the duration of moderate flows between 22,000 cfs, and 45,000 cfs and low flows between 5,000 and 10,000 cfs (Figure 5-3).

A major flood occurred in the Willamette River basin in 1964 inundating over 320,000 acres of land. Reservoir regulation held the peak discharge at Salem, Oregon, to 309,000 cfs; without the reservoirs, the estimated peak discharge would have been approximately 472,000 cfs. Major flooding also occurred in February 1996. Reservoir regulation held the peak discharge at Salem to about 243,500 cfs during that event; without the reservoirs, peak discharge would have been about 381,000 cfs.

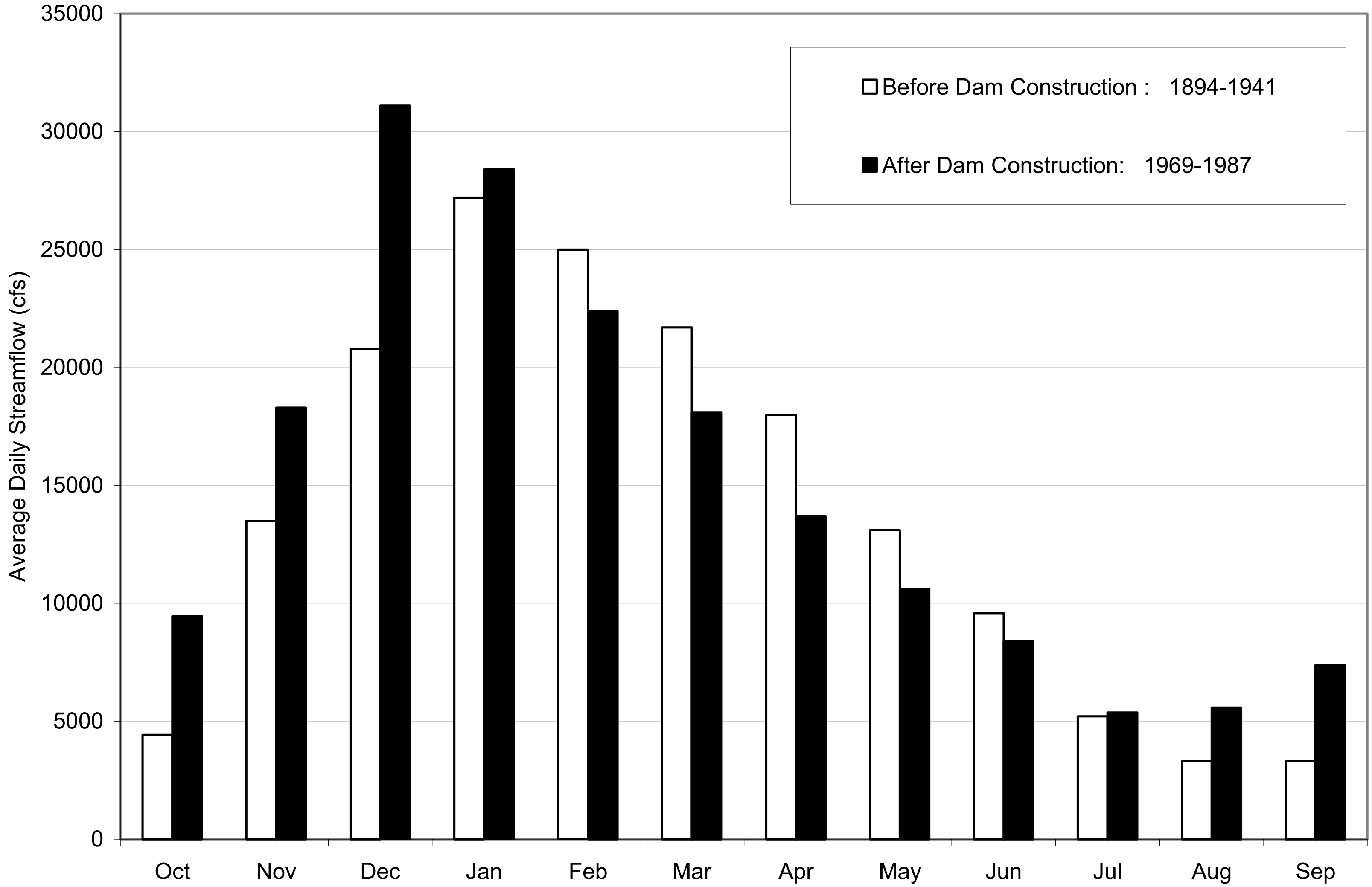

Figure 5-1. Monthly average flows at USGS Gage 14174000, Willamette River at Albany, Oregon (Moffatt et al. 1990).

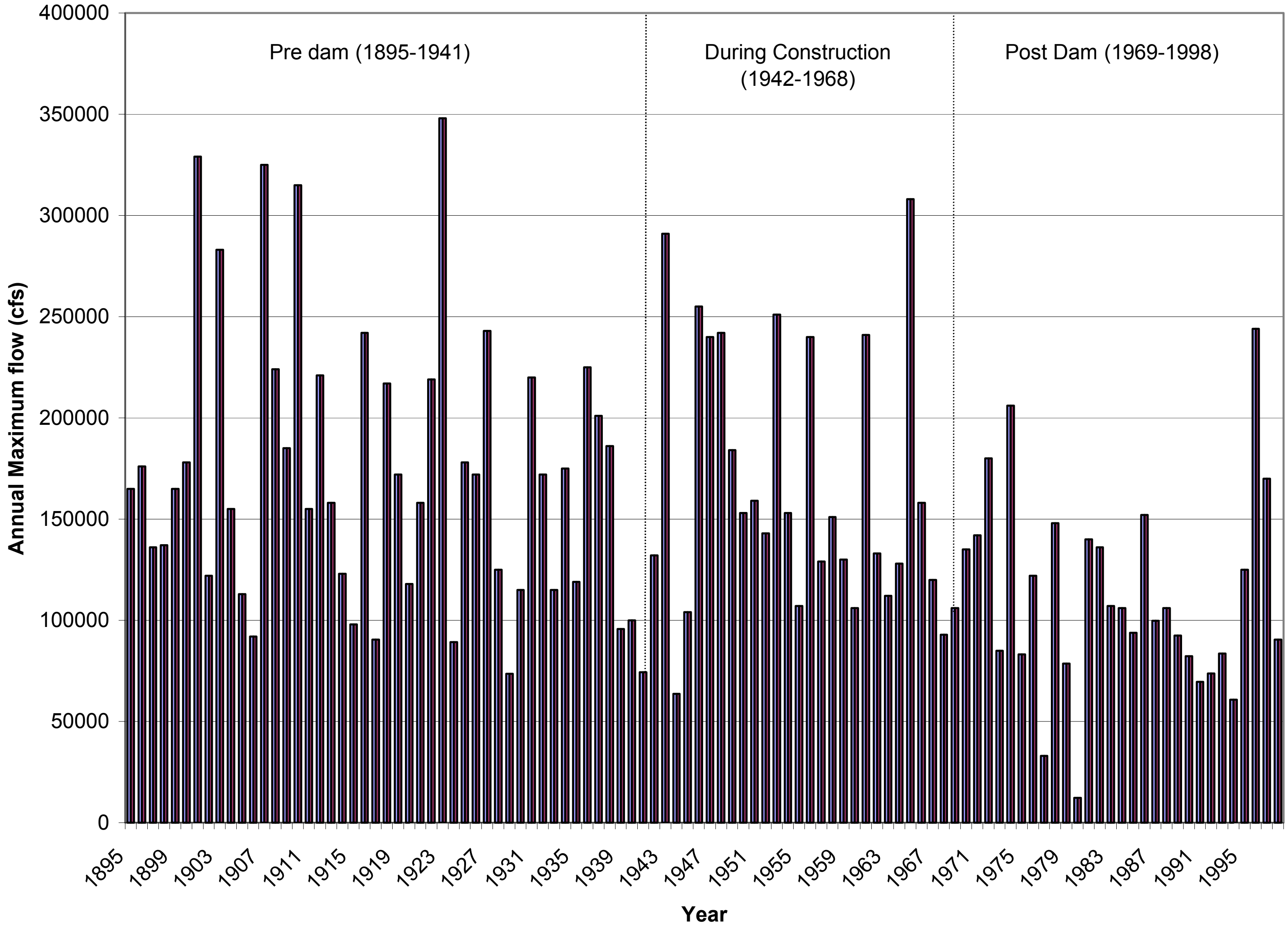

Figure 5-2. Annual peak flows at USGS Gage 1191000, Willamette River at Salem, downstream of the 13 USACE Willamette River basin projects.

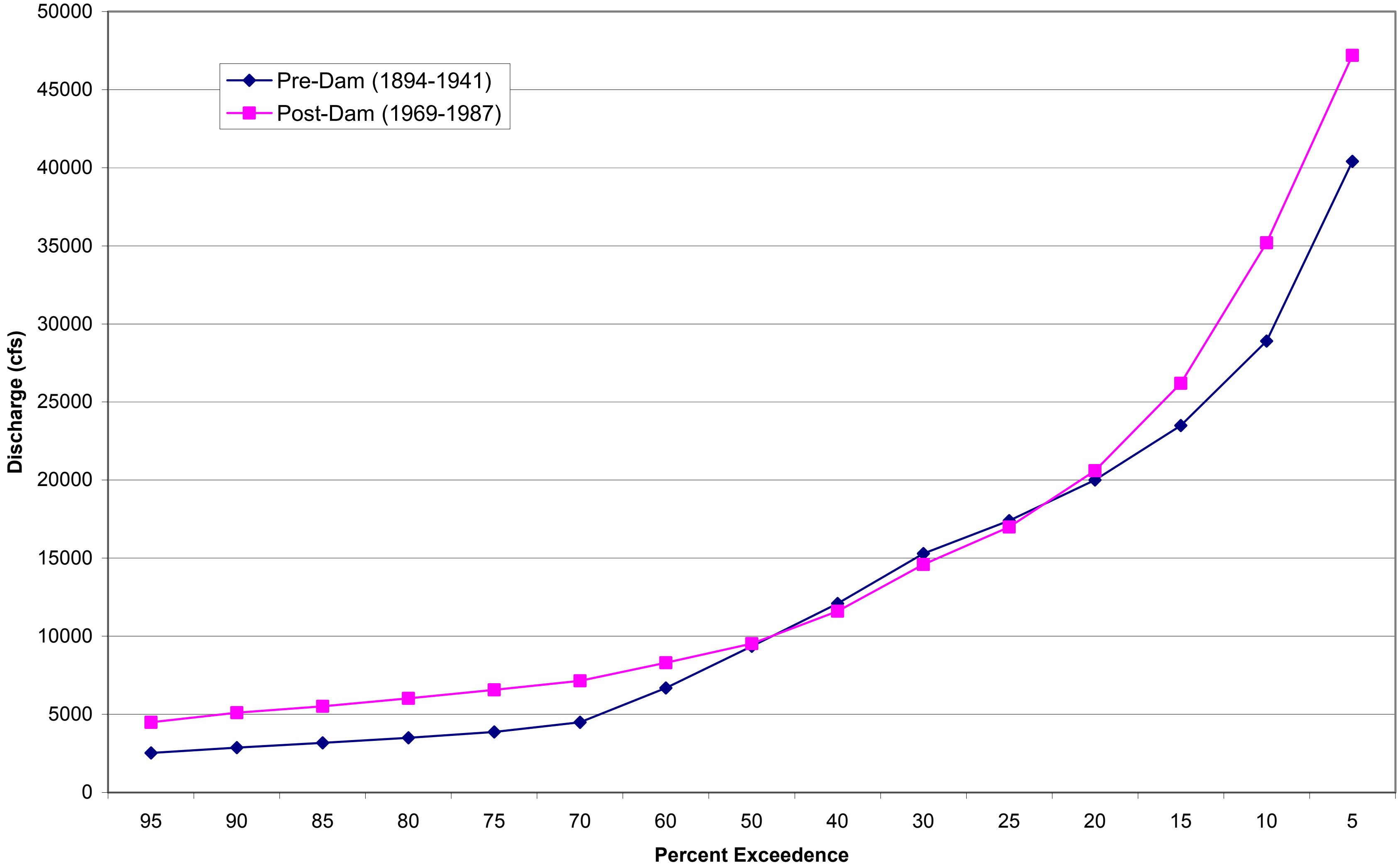

Figure 5-3. Pre- and post dam flow duration curves based on mean daily flows at USGS Gage 14174000, Willamette River at Albany, Oregon (from Moffatt et al. 1990).

Flows are naturally lowest in the late summer and early fall. Historically, low flows in the Willamette River were sustained by the slow release of water stored in the banks and alluvial aquifers connected to the river. Post-project summer flows are greater than occurred historically because storage is available at USACE facilities to redistribute flood volumes and release water later in the year for flow augmentation purposes. Minimum flow requirements have been set at Albany and Salem that are substantially greater than typical pre-project minimum flows experienced during the late summer; the average annual 7-day low flow has essentially almost doubled over pre-project flows.

Irrigation water use in the Willamette River basin is about 401,549 acre-feet annually, accounting for about 33 percent of the total water use in the basin. Commercial irrigation in the Willamette River basin dates back to 1890. Most of the early development of irrigation took place near the cities of Portland, Salem, and Eugene. Irrigation development proceeded slowly through the first four decades of this century: about 1,000 acres were irrigated by 1911, 3,000 acres by 1920, 5,000 acres by 1930, and 27,000 acres by 1940. Since 1940, irrigation development has increased by ten fold. Total irrigated acreage in 1994 was estimated between 240,000 and 290,000 acres, and water demands have increased accordingly (OWRD 1999).

In 1990, the USGS estimated that 63 percent of water for irrigation in the basin came from surface sources, and 37 percent came from groundwater sources. Before 1930, most of the water for irrigation came from surface sources. Since this time, there has been a growing reliance on groundwater sources. Irrigated lands are distributed fairly evenly across the basin. Of the land that is irrigated with surface water sources, about 13 percent is located in the upper region above Harrisburg, 24 percent in the upper mid-valley region above Albany, 32 percent in the lower mid-valley region above Salem, and 31 percent in the lower region below Salem. Table 5-2 shows the current distributions of irrigated acreage by water source in the basin (OWRD 1999).

Table 5-2. Distribution of irrigated land, type of irrigation water, and total acres of irrigated lands in four regions of the Willamette River basin, Oregon, in 1990.

Region	**Surface Water**	**Ground Water**	**Total Irrigated Acres**
Upper Region (above Harrisburg control point)	68.1%	31.9%	34,000
Mid-Valley Region (above Albany control point)	73.7%	26.3%	60,560
Mid-Valley Region (above Salem control point)	54.1%	45.9%	108,430
Lower Region (below Salem control point)	66.9%	33.1%	85,700
Totals	63.7%	36.3%	288,690

Source: US Geological Survey, 1996, Estimated Water Use and General Hydrologic Condition for Oregon, 1985 and 1990

5.1.2 Sediment Transport

The dominant mechanism for transport of sediment from hillslopes to stream channels in the Willamette River basin is mass-wasting (Swanston and Swanson 1976). In tributaries originating in the Oregon Coast Range, the predominant mass wasting processes are failure of stream-adjacent bedrock hollows and debris flows from first and second order channels (Benda et al. 1997). Mass-wasting processes in tributary basins that originate in the Cascades are more diverse. Deep-seated bedrock landslides are common, resulting in the formation of steep-sided inner gorges next to many channels (Benda et al. 1997). Shallow failures from inner gorges and bedrock hollows are also common. Sediment transport studies indicate that total sediment loads in small headwater watersheds in the Coast Range and Cascades vary spatially and temporally, ranging from 289 to 510 tons per square mile and 59 to 561 tons per square mile, respectively (Larsen and Sidle 1980). In general, tributaries draining the Cascade Range contribute coarse bed material similar or larger in size to substrates found in the mainstem Willamette River. tributaries draining the Coast Range contribute finer sized gravels and considerable sand (Klingeman 1981)

After leaving the mountains just upstream of Eugene, the Willamette River becomes a meandering system in a broad, flat valley floor consisting of alluvial (river deposited) sediments. Coarse, gravel size sediment is transported downstream during moderate to high flows, and is stored within the channel bed and banks during intervening low flow periods. The main sources of sediment to this portion of the river are bedload and suspended sediments transported in from upstream reaches and tributaries, and erosion of the unconsolidated river banks.

Construction of the Willamette River basin projects is believed to have reduced the supply of gravel to tributary channels downstream of the dams and the mainstem Willamette River. Upstream of the dams, all bedload sediment and much of the suspended load is deposited in the deep, low velocity impoundments. The response of downstream channels in the Willamette to dam construction depends on the nature of the pre-dam bed material and the magnitude of the change in both sediment and flows (Table 5-3).

Table 5-3. Generalized impacts of reduced peak flows and interception of bedload sediments on gravel bed river channel morphology.

Change in Sediment Supply	Change in Flood Peaks	Physical Effect
Large reduction (few or no downstream tributary gravel sources)	Moderate reduction (flows greater than or equal to 5 year event still occur regularly)	Loss of smaller gravel, armoring; possible channel incision; encroachment of riparian vegetation[1, 2]
Large reduction (few or no downstream tributary gravel sources)	Large reduction (flows greater than pre-dam 2 year event no longer occur)	Channel voids may fill with fines; encroachment of riparian vegetation[1]
Small to moderate reduction (downstream tributaries that contribute gravel present)	Moderate reduction (flows greater than or equal to 5 year event still occur regularly)	Loss of small gravel, armoring to first tributary, some reduction in channel storage downstream; encroachment of riparian vegetation[1,4]
Small to moderate reduction (downstream tributaries that contribute gravel present)	Large reduction (flows greater than pre-dam 2 year event no longer occur)	Channel voids may fill with fines; aggradation at tributary junctions; encroachment of riparian vegetation[1,3,4]

[1] Milhous 1982 • [2] Kondolf and Matthews 1993 • [3] Kellerhals 1982 • [4] Parker 1980

Upstream of the confluence with the Santiam River, the mainstem Willamette and its floodplain are only a few feet below the general level of the valley floor. Several miles downstream of the confluence with the Santiam River, the Willamette River begins flowing in a well defined single channel with high banks. A study of specific gage heights at Harrisburg, Albany, Salem and Wilsonville showed a definite trend of bed lowering at each site (Klingeman 1973). While no definitive cause of the degradation was identified, in-stream sand and gravel mining, construction of levees and bank revetments, and conversion of lands from forest to agricultural and urban land uses have likely all influenced the change (Klingeman 1973). Interception of sediment by the flood control projects may not have been the primary causative factor because the trend was apparent prior to construction of the dams, and because tributaries below impoundments did not consistently exhibit comparable trends (Klingeman 1973). Levee and bank revetment construction may have been more influential because confining peak flows in narrow, straight single thread channels increases the sediment transport capacity of the river (Dunne and Dietrich 1979) which, coupled with a reduction in the contribution of sediment from bank erosion, may have resulted in the development of a coarser armor layer and channel incision in the Willamette River basin (Klingeman 1973). However, reservoir interception of sediment may still contribute to the problem over the long term. Reduction of flood flows by the USACE facilities may have also influenced these processes because less energy is available to transport sediments coming from tributaries to degrading reaches located further downstream (Milhous 1982; Kellerhals 1982).

While the dams prevent the downstream transport of bedload, much of the suspended sediment continues to be routed downstream. Some of the suspended sediment may settle out in the low velocity impoundments, and some may be re-suspended on the falling limb of the hydrograph or during lower flows that erode through the deposited fines. Suspended sediment occurs in appreciable amounts in nearly every Willamette River basin stream during periods of high runoff. In general, the annual suspended sediment loads in the Coastal tributaries are about twice, and loads in channels originating in the Willamette Valley four times the amount in tributaries draining the Cascade Mountains (Wentz et al. 1998). The relationship between suspended sediment and discharge is similar for both the pre-reservoir and post-reservoir periods, although the average suspended particle size has decreased since dam construction (Wentz et al. 1998). Taken together with the work of Klingeman (1981), this suggests that a downstream source of coarser sediments and sand, such as bank erosion, may have increased in importance.

5.1.3 Bank Protection and Channelization

Bank protection activity in the Willamette system has occurred extensively over the past 100 years. The Flood Control Acts of 1936, 1938, 1950 authorized the Willamette River Bank Protection Program to allow for 450,000 linear feet of protection works. The program was intended to prevent bank erosion and protect productive farmland, roads, bridges, and other improvements. In 1971, the Senate and House Committees on Public Works expanded the program's scope to 510,000 linear feet. A summary report for this program (USACE 1989d) addressed the status of bank protection projects completed in the Willamette system. About 489,800 linear feet of erosion protection have been provided at 230 locations in the system. These projects are commonly rock revetments constructed of heavy quarry stone placed on the river banks.

Nevertheless, some bank erosion continues in the Willamette system. According to Weber (1989), of the 130 miles of river banks along the mainstem Willamette from the Yamhill River to Albany (RM 56 to 121), about 10 percent of the banks (13.5 miles) were eroding at rates considered to be moderate or severe. About 58 erosion sites have been identified, and about 225,000 tons of soil and almost 95,000 tons of gravel have been estimated to erode from the banks and into the river annually (Weber 1989). Greatest losses occur at bankfull and higher flood stages during the flood control season (December through February). Regulation of the reservoir system during the flood season often holds water levels at or near bankfull over several days to weeks. This can allow the river more time to attack its banks and for the soil of the bank to become saturated with water. Rapid dropping of river stage can then cause slumping of saturated bank material.

5.1.4 Floodplain Maintenance and Side Channel Connectivity

Historically, the unconfined Willamette River freely migrated back and forth across its floodplain. Channel migration occurred as a slow, steady erosion of the outside of a meander bend accompanied by an approximately equivalent amount of deposition on the inside of the meander bend, or rapid formation of a new channel (an avulsion) as a result of blockage of the existing channel by LWD jams or deposition of coarse sediment. Overbank flows can quickly carve out a new channel in the finer-grained floodplain when blockages occur. The Willamette River consisted historically of a mix of braided (multiple) and single channel reaches during low flow, and side channels that conveyed water only during moderate to high flows and supported successional vegetation of varying ages. Bar building was an important feature for establishing riparian vegetation and new floodplain habitat. There were also numerous abandoned oxbow lakes, sloughs and wetlands distributed across the floodplain that the river would occasionally reconnect with. Such "off-channel" habitats were historically an important component of fish habitat within the Willamette River basin, providing rearing habitat and refuge from high flows (Sedell and Froggatt 1984; Dykaar and Wigington 2000).

The quantity and quality of off-channel habitat in the Willamette River system is presently much less than was available historically because of channel bank protection works, flood control, and floodplain development (Dykaar and Wigington 2000). The length of the mainstem Willamette River between Eugene and Albany has been decreased by approximately 45 to 50 percent since 1850 (Benner and Sedell 1997). The river planform has changed from a complex multiple channel network to a simplified and often single-thread channel (Figure 5-4). Loss of side channel habitat has been attributed primarily to dredge and fill activities to improve the channel for navigation, agricultural development of the floodplain, and stream cleaning; the present channel pattern was largely set by 1946 (Sedell and Froggatt 1984). However, construction of the Willamette River basin projects has also influenced the availability of off-channel habitat by: 1) reducing flood flows that form and maintain off-channel habitats; 2) changing the hydrologic regime thereby influencing the ability of salmonids to access or escape from off channel habitats; and 3) allowing riparian vegetation to colonize formerly active floodplain surfaces (USACE 1980).

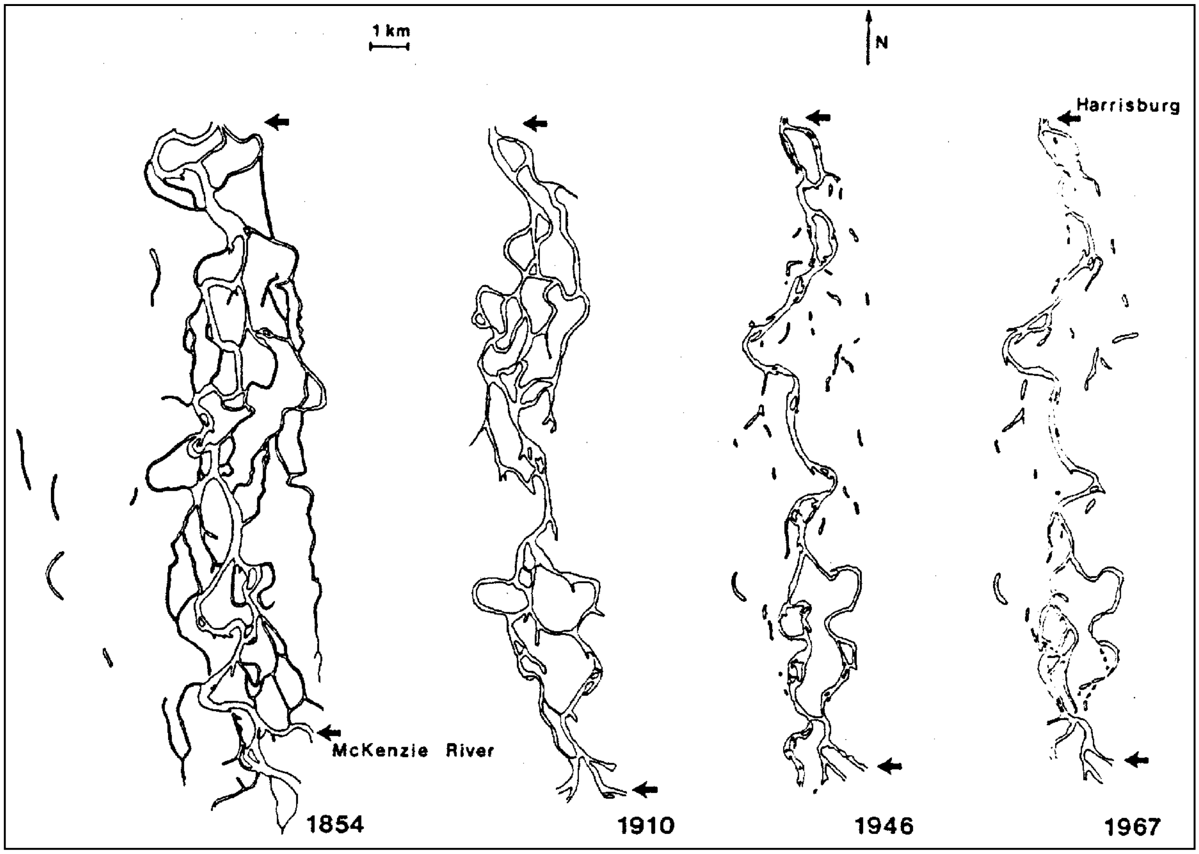

Figure 5-4. Willamette River channel simplification over time between 1854 and 1967. This 14-mile (23 km) section of river is between the McKenzie River confluence (RM 175) just downriver of Eugene to Harrisburg (RM 161) (from Sedell and Froggatt 1984).

5.1.5 Large Woody Debris Transport

LWD is an important component of fish habitat because it provides habitat space (pools) and structure (cover), provides habitat and food for aquatic invertebrates, helps retain local deposits of spawning gravel in reaches where the sediment transport capacity exceeds the rate of supply, contributes to bank stability, and can be integral to channel migration processes in alluvial reaches (Bilby and Ward 1991; Abbe and Montgomery 1996).

LWD was an important component of the Willamette River ecosystem historically. LWD contributed to the formation and movement of multiple channels in the unconfined section of river that began just upstream of Eugene (Benner and Sedell 1997). Debris jams up to 2,200 feet long formed following floods, filling the entire river channel (Sedell and Froggatt 1984). Removal of in-channel LWD has occurred throughout much of the Willamette River basin as a result of navigational improvement activities, flood control, and timber harvest practices (Benner and Sedell 1997). Sedell and Froggatt (1984) estimated amounts and effects of large woody debris in the Willamette River based on a review of early reports by the USACE and township survey plats dating to the 1850s. They estimated that between about 1870 and 1950, over 69,000 snags and overhanging trees were removed from the Willamette River (Sedell and Froggatt 1984). Construction of the Willamette Project has partially disconnected the mainstem river from its system LWD supply.

In addition to intentional clearing, human activities and resulting changes in geomorphic processes have reduced the amount of LWD inputs. Flood control operations preclude large channel-altering flows that erode into vegetated banks that could provide material to the channel. Timber harvest, and agricultural and urban development have involved clearing of vegetation within the riparian zone, and have thus reduced the source of future LWD in the unconfined mainstem and lower portions of many tributaries. Timber harvest has had a similar effect in the headwaters of most tributaries, and construction of the Willamette River basin projects has blocked the downstream transport of wood originating in the headwaters. Clearing and harvest of the riparian zone also resulted in reduced bank stability, which was then achieved artificially by constructing levees or revetments. Channelization and construction of levees and revetments have reduced the rate of channel migration in many reaches of the Willamette River, effectively stopping the movement of the channel into wooded areas. However, in some areas, the channel has continued to migrate, resulting in the abandonment of some levees that have since become "landlocked." Establishment of woody vegetation on re-enforced banks is often prevented because of flood control concerns. Loss of riparian vegetation is also associated with the elimination of shade and reduced input of organic detrital matter.

5.1.6 Fish Habitat

The substrate compositions above and below Willamette Falls are markedly different because of the gradient change and differences in hydraulics. Gravel and cobble substrates are common above Willamette Falls, whereas below the falls the substrates are mostly sand and finer sediments (ODFW 1990b). Substrate embeddedness is generally less than 50 percent in the upper reach, and nearly 100 percent in the lower reaches (ODFW 1990b). Historical accounts of salmon spawning in the mainstem are contradictory, but in general, substrates located throughout most of the mainstem are unsuitable for spawning by anadromous salmonids (McIntosh et al. 1995). Surveys conducted in the late 1930s noted that the mainstem river lacked suitable spawning habitat from a point about seven miles downstream of the confluence with the McKenzie River to the mouth because of sluggish flow, increasing amounts of pollution, high temperatures, paucity of good spawning riffles, and a high percentage of fine sediments. The section between the McKenzie River and the Coast Fork Willamette River was also noted to contain relatively little spawning habitat because the river was generally wide, slow, and deep (McIntosh et al. 1995). The Oregon State Game Commission (1963) counted 20 potential spawning bars in the mainstem between the Long Tom River and the Yamhill River, of which nine were judged to be useable at most flows. Thompson et al. (1966) noted that most spawning gravel was located upstream of Corvallis, although most spawning activity occurred in the tributaries. Fulton (1970) noted that some suitable spawning habitat existed in the mainstem throughout the upper half of the river that was used by spawning steelhead. Mountain whitefish, a native non-anadromous, broadcast spawning salmonid species is reported to spawn throughout the river (Altman et al. 1997).

Bank modification may have reduced rearing habitat quality and quantity in the mainstem Willamette River for juvenile salmonids and other fish species. Smooth, steeply sloping banks provide few velocity refugia during high flows, and rip-rapped banks support lower fish densities than natural banks, which generally have a higher percentage of their surface area represented by wood, cobble and boulder, aquatic plants or undercuts (Beamer and Henderson 1998; Peters et al. 1998).

Tables 5-4 and 5-5 summarize estimates of habitat carrying capacity for naturally produced spring chinook salmon and winter steelhead in the Willamette system. The variability in results depending on method used underlines the difficulty in accurately estimating system-wide carrying capacity.

Altman et al. (1997) compiled information on the abundance and distribution of algae and benthic invertebrates in the mainstem. Diatom algae species dominated the algal community in the lower Willamette River between RM 7 and RM 50; diatoms are considered to be of high food value for various aquatic fauna (Johnson et al. 1985, cited in Altman et al. 1997). Below RM 50, diatoms have been primarily in the suspended phytoplankton, whereas above RM 50 they were found primarily in the periphyton (algae attached to the surface of rocks and other substrates). This likely reflects the difference in substrates between the upper and lower reaches that are available to be colonized by algae. In the upper reaches, blue-green algae taxa were more numerous than diatoms. In general, phytoplankton abundance and diversity increased in the downstream areas.

Table 5-4. Estimates of smolt production capacity for natural production of spring chinook salmon in the Willamette system (ODFW 1990a, 1990c).

	Smolt Carrying Capacity	
Tributary Subbasin	**NPPC Model** [1]	**Alternate Method** [2]
Clackamas subbasin	1,860,469	260,055
Molalla/Pudding subbasin	624,706	45,952
Santiam subbasin	910,020	367,614
North Santiam	na	245,076
South Santiam	na	122,538
McKenzie subbasin	2,113,247	1,072,207
Middle Fork subbasin	79,480	na
Mainstem Willamette River	165,584	na
Other minor tributaries	275,438	45,952
Total	6,028,944	1,791,779

[1] Northwest Power Planning Council Standard Model

[2] Gradient Area Flow Methodology developed by Washington Department of Wildlife.

Table 5-5. Estimate of smolt production capacity for natural production of winter steelhead in the Willamette system (ODFW 1990a).

	Smolt Carrying Capacity	
Tributary Subbasin	**NPPC Model** [1]	**Alternate Method** [2]
Middle Fork Willamette	55,521	21,447
Coast Fork/Long Tom	0	na
Coast Range	172,508	56,013
Calapooia	34,485	20,452
Santiam	381,663	150,544
Molalla/Pudding	201,797	105,164
Tualatin	84,795	na
Clackamas	465,088	na
Total	1,395,857	353,620

[1] Northwest Power Planning Council Standard Model

[2] Gradient Area Flow Methodology developed by Washington Department of Wildlife.

The composition of benthic invertebrates in the mainstem Willamette River is also influenced by the composition of the substrate. In general, macroinvertebrate species composition is less diverse and less abundant in soft-bottom habitats than in riffle/run habitats (Altman et al. 1997). A study of macroinvertebrates between RM 57 and RM 185 indicated that water quality degradation, rather than habitat degradation appeared to account for the biological impairment of downstream macroinvertebrate communities relative to upstream reference sites (Altman et al. 1997). Systematic, long-term data collection of macroinvertebrates within the Willamette system is generally lacking.

As noted above, by the 1920s and up to the late 1960s, the Willamette River experienced extremely poor water quality (WRTBF 1997). Urban and industrial wastes were dumped directly into the Willamette River without any type of treatment. From the turn of the century until the 1960s, the cities along the river used the Willamette River as an open sewer for human and industrial wastes, even though water quality problems were recognized in Portland in the mid-1920s. Inputs of effluents resulted in "oxygen blocking" within the lower river, particularly below RM 17, where oxygen levels would often fall below 5 mg/l in July, August, and September. The low levels effectively blocked fish migrations during that period (ODFW 1990b). Regulations that mandated installation of secondary waste treatment facilities helped improve water quality conditions. By the late 1950s, most major cities on the Willamette River were required to install secondary waste treatment facilities, by 1960, all municipalities below Salem were required to do likewise. Pulp and paper mills had primary waste treatment facilities installed by 1969 and secondary facilities by 1972. Since 1972, all industrial and municipal plants on the Willamette River have facilities that provide secondary treatment of wastewater (ODFW 1990b). Construction of the Willamette reservoirs also played a role in improving summer water quality by augmenting river flows.

Low oxygen conditions reportedly continue to persist (albeit at less drastic levels) in the lower Willamette River, and water quality problems can be locally devastating to aquatic life (ODFW 1990b). In developed areas, storm water runoff carries pollutants from surrounding roads, parking lots, and roof tops (Anderson et al. 1996). Trace metals are found in high concentrations in industrial sloughs. Levels of nitrogen and phosphorous in the Willamette River often exceed water quality criteria. Reaches of the river system that violate state of Oregon water quality standards are listed by the ODEQ on the state's 303(d) list of impaired water bodies, in accordance with the Federal Clean Water Act. The state of Oregon has classified the water quality of the entire mainstem Willamette River below the confluence of the Coast Fork and Middle Fork Willamette rivers on the Federal Clean Water Act's 303(d) list as being impaired due to high summer-time water temperatures (ODEQ 1998). In addition, the reach from the

Willamette Falls to the mouth of the river is listed due to high levels of fecal coliform bacteria, high levels of mercury in fish tissues, and for recent observations of fish skeletal deformities (ODEQ 1998). There is also an area that is impaired by pentachorophenol and arsenic. Most of the upper Willamette River is also listed as impaired due to high levels of mercury in fish tissues; one reach is listed for fish skeletal deformities; another reach is listed due to high levels of fecal coliform bacteria (ODEQ 1998).

Water quality in the Willamette River basin has been studied intensively since 1991 as part of a program administered by the Willamette River Basin Technical Advisory Steering Committee. Additional water quality investigations have been completed through the USGS National Water-Quality Assessment Program (Wentz et al. 1998). These studies have included investigations and modeling of point and nonpoint-source water quality, evaluations of the aquatic community, evaluations of nutrient and periphyton growth, time-of-travel and hydrologic-flow modeling, sediment transport, trace elements and organic chemicals, measurements of sediment-oxygen demand, and investigation of factors controlling DO and pH in the upper Willamette River and major tributaries (Pogue and Anderson 1995).

5.1.7 Fish Distribution

The historical distribution of many species within the mainstem Willamette River was influenced by Willamette Falls located at RM 26.6, which has always restricted fish passage. Historically, the falls were probably negotiable for upstream migrating anadromous salmonids and Pacific lamprey only during the winter and spring high flow period. In 1873 navigational locks at the falls were completed that allowed for some fish passage, and in the mid-1880s, a crude rock fishway was constructed (ODFW 1990b). The effectiveness of this fishway was compromised, however, by development of a dam constructed around the lip of the falls in 1903-1904 that diverted flows away from the entrance to the fish passage structure. It was not until 1971 that the current fish ladder was fully operational. Continued problems with the fish ladder and adult passage at the falls include poor access for equipment and personnel at the site, and absence of an automatic window cleaner at the counting station (ODFW 1990b). While it has not been documented, it is suspected that some adults may "fall back" over the falls once they negotiate the ladder, resulting in overcounting. Stranding of adult steelhead in pools below the falls is another problem (ODFW 1990b).

Since 1891, the falls have been developed for hydroelectric production and there are now 52 turbines operated jointly by several entities. Since 1960, the turbines have been operated by

Portland General Electric, Crown Zellerbach, and Publisher's Paper Commission under a 50-year license by the Federal Power Commission (ODFW 1990b).

The hydroelectric turbines built at the falls influence downstream fish passage survival. The turbines have been shut down during the majority of the downstream migration period of salmonid juveniles since the 1980s, to prevent mortality (ODFW 1990b). The closures are generally timed to coincide with the peak periods of hatchery releases. A significant portion of the early spring and winter outmigrant populations, including those of wild stocks, are not protected by this seasonal closure (ODFW 1990b).

The following listed, candidate, and related species use, or may have historically used the mainstem Willamette River at some point in their life cycle:

Spring chinook salmon are native to the Willamette River, with the mainstem primarily a migration corridor for adults and smolts. The mainstem has relatively little potential for spawning, but provides some rearing habitat for juveniles (ODFW 1990b). Only two redds were observed in 1998, approximately 4 miles downstream of the McKenzie River (Lindsay et al. 1999). Historical surveys in the 1930s indicated that spring chinook did not use the mainstem for spawning; the majority migrated to the McKenzie and Middle Fork Willamette river subbasins (McIntosh et al. 1995). These surveys were conducted after the mainstem had suffered extensive habitat degradation because of agriculture, logging, industry, and sewage discharges. The area of the Middle Fork Willamette above the mouth of the McKenzie River probably holds the most potential for natural production, but any mainstem spawning that did occur could be influenced by releases of warm reservoir water during egg incubation and other water quality problems (ODFW 1990b; WRBTF 1997). The only self-sustaining natural population in this ESU is thought to live in the McKenzie River (64 FR 14308).

Native spring chinook populations may have been subjected in the first half of the 20th century to selective pressures induced by commercial development of Willamette Falls, water pollution, and numerous anthropogenic barriers including racks maintained by the state chinook hatchery program that completely blocked the migration of several runs, including the North and South Santiam, the McKenzie, and the Middle Fork Willamette rivers, in order to collect eggs. The racks were placed across the above rivers each spring, the fish were held throughout the summer behind the racks, and the eggs taken in late August and throughout September (Mattson 1948). The size of the Willamette River spring chinook runs prior to 1946 was never ascertained, but estimates based on egg takes at the hatchery racks indicate that by 1946 the runs were five times less than they were in the 1920s and 1930s (Mattson 1948).

Winter steelhead trout spawned and reared in the upper Willamette mainstem historically. Currently, winter steelhead use the mainstem Willamette River primarily as a migration corridor on their way to spawning and rearing habitat in the tributaries (ODFW 1990b; Fulton 1970). Willamette Falls was naturally, but selectively, passable by winter steelhead before it was laddered in 1885. This natural barrier likely formed a gene flow barrier between the rainbow trout and steelhead populations above and below it (Kostow 1995). Native steelhead primarily used tributaries on the east side of the basin, with cutthroat trout predominating in streams draining the west side of the basin (Busby et al. 1996). It is suspected but unconfirmed that steelhead were not present historically in the McKenzie and Middle Fork Willamette rivers, although resident rainbow trout were abundant in both basins. The majority of steelhead spawning activity was concentrated historically in the North and South Santiam river basins, including above the current dam locations (64 FR 14517). Wild production of winter steelhead in the Willamette River basin has been supplemented with hatchery production of native wild stock since 1952 and with Big Creek stock (not included in the listing) since 1966 (ODFW 1990b).

Summer steelhead trout are not native to the Willamette River above Willamette Falls and are not considered to be a member of the Upper Willamette steelhead ESU. Summer steelhead were introduced to several tributaries above the falls beginning in the late 1960s. Natural production of summer steelhead appears to be low (2.5% of total run in 1981), and the population is maintained largely by releases of hatchery fish (Busby et al. 1996). The mainstem Willamette supports little if any successful spawning of summer steelhead, and is instead used by the fish as a migration corridor (ODFW 1990b). Warm water (above 17.2°C) in the mainstem increases the incidence of bacterial infection, and these disease problems are aggravated by late smolt emigration resulting from delayed passage or small size at release (ODFW 1990b). In addition, low water levels and high temperatures during smolt emigration are suspected of contributing to specific reduced run sizes (ODFW 1990b). The recent run size of summer steelhead over the Willamette Falls was 9,700 fish (Busby et al. 1996). Recreational fishing for summer steelhead is popular in the Willamette River basin but most of the angling occurs in the tributaries (ODFW 1990b).

Fall chinook salmon are not native to the Willamette River above Willamette Falls and are not included in the Upper Willamette Chinook ESU. Fall chinook were first introduced above the falls in 1964 (ODFW 1990b). In contrast with spring chinook, fall chinook do spawn in the mainstem Willamette River. Spawning surveys conducted between 1976 and 1988 determined that approximately 60 percent of fall chinook spawn between RM 132 (Corvallis) and RM 175 (Coburg) (ODFW 1990b). Fall chinook were initially released to establish a self-sustaining run above Willamette Falls. Today, fall chinook are released to produce fish for ocean and Columbia River fisheries (ODFW 1990b).

Coho salmon are not native to the upper Willamette River basin. The Clackamas River, which enters the mainstem below Willamette Falls, historically and currently supports the largest naturally spawning populations of coho salmon in the basin that are likely of native origin (Weitkamp et al. 1995). Willamette Falls may not have completely denied access by coho to the upper Willamette River basin. Small runs of coho were noted to have used the Molalla and Tualatin rivers historically (Parkhurst et al. 1950), and straying coho adults are occasionally found in the Willamette River basin above Willamette Falls. Hatchery releases of coho in the 1970s and 1980s occurred primarily in the lower river tributaries (Olsen et al. 1992).

Chum salmon are not found in the Willamette River above Willamette Falls, and chum salmon populations are very depressed to extinct throughout the Oregon subbasins of the lower Columbia River (Kostow 1995). It is unlikely that chum ever migrated past Willamette Falls, as they show little inclination for surmounting river blockages and falls (Johnson et al. 1997).

Sockeye salmon are not native to the Willamette River basin (Kostow 1995). In 1967 and 1968, sockeye salmon were introduced into the Green Peter Reservoir on the Middle Santiam River (Olsen et al. 1992). Although hatchery sockeye are no longer released to this system, sockeye are believed to have residualized in the reservoir and contribute, along with releases of hatchery kokanee, to a sport fishery in the reservoir (Olsen et al. 1992).

Cutthroat trout occur in the Willamette River and tributaries downstream of Willamette Falls (Kostow 1995). Although the possibility has been raised that sea-run coastal cutthroat could migrate above the falls during high flows, the upper Willamette River has probably never supported a substantial anadromous population of cutthroat trout. The primary life-history form of cutthroat above Willamette Falls appears to be resident freshwater, a type that seems relatively rare below the falls (Orlay et al. 1999). Fluvial, adfluvial, and resident life history types of cutthroat trout are present throughout the Willamette mainstem and tributaries above Willamette Falls (Kostow 1995).

Bull trout in the Willamette River basin were most recently comprised of several resident populations and at least one fluvial population in the McKenzie and Middle Fork Willamette rivers (Kostow 1995). These populations are considered to be the only remaining group of Oregon bull trout west of the Cascade Mountains (Kostow 1995). The status of bull trout in the Middle Fork Willamette River will likely be changed to “probably extinct” in the near future

(Buchanan et al. 1997) if recent reintroduction activities succeeded in reestablishing populations (Taylor and Reasoner 1998). Table 4-9 lists the reported historical distribution of bull trout in the Willamette River basin.

Oregon chub are endemic to the Willamette River basin and were historically found throughout the river system in slack water, off-channel habitats (USFWS 1998a). Today, small isolated populations occur in only approximately 20 locations (USFWS 1998a). Details on Oregon chub populations and habitat conditions are presented in the USFWS recovery plan for the species (USFWS 1998a).

The fish assemblage in the lower Willamette River, from the mouth to RM 15, is dominated by northern pikeminnow, a native species (formerly known as northern squawfish). The next most abundant species are non-native warm-water fish including black crappie, white crappie, largemouth bass, smallmouth bass, and walleye (Altman et al. 1997). Estuarine species are also found below the falls (Table 5-1).

5.2 SANTIAM RIVER

The mainstem Santiam River lies entirely in the Willamette Valley floodplain, and has an estimated 1,529 miles of stream in its basin. The river enters the mainstem Willamette River from the east at RM 109. The river channel is wide and largely exposed to the sun, which results in shallow, warm waters during low-flow periods. Maximum water temperatures exceeded 21.1°C at several sites during the period 1950 through 1957 (Willis et al. 1960). The average gradient of the mainstem river was estimated to be approximately 0.1 percent. The substrate composition is largely gravel, but spring chinook and winter steelhead are not known to historically or currently use the mainstem for spawning (Lindsay et al. 1999). The mainstem appears to serve as a migration corridor and possibly for steelhead rearing (Fulton 1968, Fulton 1970). In 1940, the mainstem contained 22.5 resting pools per mile (McIntosh et al. 1995); in 1989 there were 7.6 miles of levee and revetments along the 11 mile length of the mainstem Santiam River (USACE 1989d).

The North and South Santiam rivers are major tributaries that accounted for the majority of historic chinook and steelhead production in the Santiam River basin, and converge at approximately RM 11. A small tributary, Chehulpum Creek, enters the Santiam River near RM 4; the stream is 6 miles long, flat, and has a muddy bottom at the Highway 99 crossing. Current water quality problems in the river basin include elevated temperatures and sedimentation

(ODFW 1990c). Substantial amounts of water are diverted from the North and South Santiam rivers for municipal, industrial, power generation, and agricultural purposes (ODFW 1990c).

5.2.1 North Santiam River

The North Santiam River drains the western slope of the Cascade Mountains and is approximately 92 miles long. The main tributaries are the Little North Santiam and Breitenbush rivers, and Blowout and Marion creeks. The Little North Santiam River is the only major tributary that enters the river downstream of the Big Cliff and Detroit dams (Table 5-6).

Table 5-6. Major streams of the North Santiam River subbasin, Oregon, with fish production potential (data compiled from Mattson 1948; Willis et al. 1960; Fulton 1968; Fulton 1970; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present ESA Listed Fish Species
Downstream of Big Cliff Dam		
North Santiam River	47	OC, WSt, SCh, BT
Little North Santiam River	30	WSt, SCh
Upstream of Detroit Dam		
North Santiam River	38	WSt, SCh, BT
Blowout Creek	12	WSt
Breitenbush River	14	WSt?, SCh
NF Breitenbush River	8	unknown
SF Breitenbush River	8	WSt?, SCh
Marion Fork	7	SCh

OC = Oregon chub • WSt = Winter steelhead • SCh = Spring chinook • BT = Bull trout • ? = possible

The upper river flows through a narrow, rocky, and steep forested canyon in which the Detroit and Big Cliff projects are located. The canyon reach continues for approximately 7 miles downstream of Big Cliff dam. The headwaters of the North Santiam River are characterized by steep drainages that have incised through resistant Pleistocene basalts and andesites (Walker and MacLeod 1991). Occasional glacial deposits are mapped at higher elevations in the drainage. Bedrock in the vicinity of the Detroit and Big Cliff projects is composed primarily of undifferentiated tuffaceous materials that can range from easily erodible to highly resistant. Numerous ancient deep-seated landslides have been mapped along the channel within the canyon, and these features probably periodically contribute large amounts of sediment to the North Santiam River (Walker and MacLeod 1991).

The lower 27 miles of the North Santiam River flows through a relatively wide valley and the gradient is slight (<0.3%) (Parkhurst et al. 1950). By 1960, the North Santiam River was heavily used for agriculture. At RM 50, near the town of Gates, the canyon widens somewhat and a narrow band of Holocene alluvium borders the channel (Walker and MacLeod 1991). The gradient decreases somewhat, and the channel begins to develop a meandering planform. Downstream of Mehama near RM 37, the North Santiam River exits the Cascade foothills and flows onto the wide alluvial valley formed by the Willamette River. The channel becomes sinuous and was described in 1947 prior to construction of the Big Cliff and Detroit dams as being "crooked and frequently divided by large islands" (USACE 1947).

The profile of the upper river generally reflects the transition from resistant volcanic basalts and tuffaceous deposits to easily eroded alluvial. The channel slope decreases from approximately 1.2 percent upstream of Detroit reservoir to approximately 0.7 percent through the narrow alluvial valley. The gradient changes from moderate to moderately steep at approximately RM 43, roughly two miles downstream of Big Cliff Dam. Downstream of the confluence with the Little North Santiam River, the channel slope drops to less than 0.2 percent.

Approximately 65 percent of the North Santiam River watershed is public land. The headwaters originate in the Mount Jefferson Wilderness area of the Willamette National Forest (ODFW 1990c). The entire Detroit Dam and reservoir are located within the Willamette National Forest. The smaller Big Cliff Dam and reservoir are located downstream of the Detroit Dam and outside of the national forest boundary. Timber harvest activity has been extensive outside of the wilderness area. The Breitenbush River was noted to have serious bedload, erosion, and siltation problems and has been targeted by the USFS for stream rehabilitation efforts (Skeesick and Jones 1988). Timber activities along the North Santiam have also resulted in an estimated 3.3 miles of river where roads have eliminated riparian vegetation and an additional 29.6 miles of streams that lack sufficient riparian vegetation due to clear cuts (Skeesick and Jones 1988).

Gold and silver mining has occurred in the Little North Santiam watershed (ODFW 1990c). Most residential development is downstream of the USACE dams on the valley floor and in the foothills.

Anthropogenic obstructions and diversions were historically numerous and problematic on the mainstem North Santiam River. In 1960, there were 9 separate dams or diversions affecting fish migration (in addition to the Detroit and Big Cliff dams), which do not possess facilities for upstream fish passage. Upstream fish passage was also obstructed prior to construction of the two USACE dams by a hatchery fish rack near the present location of the Detroit Dam

(Parkhurst et al. 1950). The rack was operated to block all salmon and steelhead during their spawning migrations, although occasionally it was washed out by floods and anadromous fish were then able to spawn above the rack (McIntosh et al. 1995). Until 1921, the policy was to transfer most or all of the eggs away from the spawning streams, and into other river systems (Cone and Ridlington 1996). The current Minto fish weir, located approximately 2 miles downstream of Big Cliff Dam is a permanent concrete structure that blocks upstream passage of all salmonids. Adults are not presently transported above the dams. Some chinook fry are released into Detroit Reservoir where they remain throughout their life and contribute to the sport fishery (Hunt 1999). It is unknown whether this population contributes to runs below the dams.

The Santiam Water Control District owns and operates a system of diversions and canals in the North Santiam River between RM 15 and 20 (near Stayton) for irrigation and hydroelectric production. This system plus several other unscreened diversion structures create low flow conditions in parts of the North Santiam River (Smith 1999a; ODFW 1990c). During the summer, diversion of water in to the north channel at Stayton leaves little flow for rearing juveniles in the south channel (ODFW 1990c).

Detroit Reservoir is subjected to extreme fluctuations over the course of the flood control season and is characterized by a steeply sloping shoreline. These features limit the productivity of the lake water, although the reservoir does contain ample quantities of zooplankton, the primary food organism for rainbow trout in the reservoir (Wetherbee 1965). Drawdown of the reservoir exposes falls in the North Santiam and Breitenbush rivers and Blowout Creek that may limit upstream fall migrations of spawning kokanee (Wetherbee 1965).

5.2.1.1 Hydrology

The North Santiam River drains an area of approximately 730 square miles. Streamflow in the North Santiam River basin reflects the same general seasonal distribution as the mainstem Willamette, with the majority of runoff occurring from October through March, and low flows during July and August. A small secondary peak occurs during April and May as a result of snowmelt runoff from higher elevations. Detroit Dam controls flows from approximately 438 square miles of drainage area. Big Cliff Dam smoothes out abrupt flow changes that result from power generation at Detroit Dam.

Flood control operations at Detroit Dam have decreased the magnitude and frequency of extreme high flow events. Prior to construction of Detroit and Big Cliff dams, the highest flow recorded in the North Santiam River was 76,000 cfs (USGS 1997). Flows greater than 40,000 cfs were not uncommon (see Appendix F). Since completion of the existing USACE flood control projects, unregulated inflows from tributaries such as the Little North Santiam River continue to produce flood events comparable to all but the largest pre-dam flows. Flows as high as 67,200 cfs have been recorded at the Mehama gage, but the two-year recurrence interval event has decreased from approximately 34,200 cfs to 19,700 cfs. Upstream of the Little North Santiam River, the effects of Detroit Dam are more pronounced. At the Niagara gage, the pre-dam, two-year return interval event was about 21,400 cfs; since completion of Detroit Dam in 1954, the two-year return interval event has been reduced to about 11,000 cfs, and no flows greater than 18,700 cfs have occurred (see Appendix F).

Flows are naturally lowest in the late summer and early fall. The lowest mean daily flow recorded at Mehama prior to construction of the Detroit and Big Cliff dams was 420 cfs, and the average daily flow in August was 781 cfs. Since construction of Detroit and Big Cliff dams, no flows lower than 682 cfs have been recorded at the Mehama gage, and the average daily flow in August has increased to 1,310 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically, because storage is available at USACE facilities to redistribute flood volumes and release water later in the year for flow augmentation purposes.

There are no diversions upstream of Mehama (USGS 1997). The Salem canal diverts water from the North Santiam River at Stayton for irrigation and power. The majority of the diverted water is then directed into the Willamette River near Salem by way of Mill Creek. Another canal, the Stayton Canal also diverts water from the North Santiam River at Stayton for irrigation, some of which is returned downstream.

5.2.1.2 Sediment Transport

Construction of Big Cliff and Detroit dams blocked transport of sediment supplied from almost 60 percent of the drainage area. It is likely that that area contributed an even larger proportion of the total sediment load because of steeper slopes and higher sediment transport rates than downstream. Sediment supplied to the mainstem following construction of the dams is limited to material supplied from landslides along the mainstem, and gravel delivered by Rock Creek and the Little North Santiam River. Bank erosion also contributes some sediment to alluvial reaches without hardened banks.

There is little documentation available regarding the effects of dam construction on sediment transport in the North Santiam River. All sediment from upstream reaches is trapped behind the dams. However, the sediment transport capacity has been substantially reduced within this reach because maximum flows are less than the pre-dam two-year return interval event. The canyon reach is largely controlled by bedrock and, coupled with the reduction in sediment transport capacity, it is unlikely that downcutting or major changes in channel morphology have occurred immediately downstream of Big Cliff Dam. Prior to dam construction, gravel and cobble were likely retained only behind flow obstructions and roughness elements such as bedrock outcrops, boulders, and large logs, and it is likely that such storage sites have always been patchy in this reach. Existing high flows are probably adequate to mobilize these stored sediments and transport them downstream. Over time, the overall amount of substrate suitable for use by spawning salmonids could have declined in this reach because of the reduced supply from upstream.

The effects of flow regulation and disruption of sediment transport on the North Santiam River are probably greatest in the narrow alluvial canyon reach between RM 39 and RM 50. An evaluation of the downstream progression of sediment waves suggest that gravel-sized sediment may move downstream as much as 5,000 feet per year; however, the downstream extent of armor layer development in a regulated river, the Green River in Western Washington was estimated to be approximately 2,000 feet per year (Perkins 1999). The actual rate would be expected to vary locally based on stream size and gradient. In the absence of site-specific information, the downstream progression of armor layer development in the Willamette system is assumed to be 2,000 feet per year for the purposes of this biological assessment. Assuming the effects of degradation extend downstream at a rate of approximately 2,000 ft per year, the effects of Big Cliff and Detroit dams could have begun to influence the alluvial canyon reach upstream of Mehama by around 1971. Surveys conducted in the alluvial reach upstream of Mehama in 1937 and 1940 reported that “larger boulders and bedrock predominate, but a good supply of gravel suitable for salmon spawning are present” (Willis et al. 1960; McIntosh et al. 1995). Substantially reducing the sediment supplied to alluvial reaches is generally expected to result in a coarsening of the substrate. Since the gradient remains moderately high through this reach, even post-dam flows are probably capable of mobilizing gravel and small cobbles. However, the reduced transport capacity has probably prevented significant downcutting.

Downstream of Mehama, the substrate historically was described to be composed of "largely gravels, many of which were too large for salmon spawning; however, many gravel bars and riffles well suited for salmon spawning are present” (Willis et al. 1960; McIntosh et al. 1995). Contributions of sediment by the Little North Santiam River may partially offset the lack of sediment supply from upstream reaches. An analysis of specific gage curves on the North Santiam at Mehama for the period from 1935 to 1965 did not reveal evidence of degradation resulting from construction of Big Cliff and Detroit dams (Klingeman 1973). Assuming that the leading edge of degradation travels downstream at approximately 2,000 feet per year, effects of the dams would not be expected to appear at the Mehama gage until the year 2011. The specific gage curves for the Santiam River at Jefferson revealed a gradual lowering that influenced low and intermediate flows. The change was tentatively attributed to bank protection works and sand and gravel mining in the channel, although degradation of the Willamette River was also noted as a possible influence (Klingeman 1973).

5.2.1.3 Bank Protection and Channelization

In 1947, the USACE noted that construction of 20 miles of levees with an average height of 5 feet would be required to provide adequate channel capacity for controlled flood discharges released from Big Cliff and Detroit dams (USACE 1947). However, the cost required to construct the structures exceeded the benefits and the projects were consequently assigned a low priority. As of 1989, a total of 3.2 miles of channel bank in the lower North Santiam River were protected by rip-rap or revetments, primarily along the lower 20 miles of the river upstream of the confluence with the South Fork (USACE 1989d).

5.2.1.4 Floodplain Maintenance and Side Channel Connectivity

Absent specific studies, it is likely that reduction in flood flows, sediment supply and large woody debris have all probably contributed to a reduction in habitat complexity and floodplain function in the alluvial portion of the North Santiam River below RM 50. Alluvial reaches of the North Santiam River were shaped during floods when the flow had sufficient power to transport coarse sediment and create erosional and depositional bedforms (Leopold et al. 1964). Organic matter and nutrients are also exchanged when floodplain surfaces are inundated (Molles et al. 1995). Riparian plants are adapted to flooding and many regenerate only on newly exposed bar surfaces or through vegetative sprouting following disturbance (Niiyama 1990; Nilsson et al. 1991). Reducing the magnitude and frequency of flood peaks allows vegetation to encroach on existing surfaces that are no longer frequently inundated and prevents the creation of new bars and islands (Ligon et al. 1995). Such changes may have occurred and simplified habitats in the North Santiam River in these manners, similar to elsewhere in the Willamette system (EA 1991a; Minear 1994; Benner and Sedell 1997). The extent to which this has occurred is unknown, however.

5.2.1.5 Large Woody Debris Transport

There is little information available on pre- and post dam LWD loadings in the North Santiam River. Like sediments, LWD that was formerly transported downstream from forested headwaters is now trapped behind the dams. Log drives and removal of wood for navigation and flood control purposes were common practices historically on Oregon rivers (Sedell and Froggatt 1984). These practices, coupled with prevention of downstream transport by the dams, have probably resulted in an overall decline in the amount of in-channel LWD found within the North Santiam River.

The effects of reduced LWD loading are likely to have been most pronounced in the alluvial reaches of the North Santiam River. LWD is usually less stable in high energy, confined reaches such as the canyon reach where pools are controlled more by bedrock. LWD was probably historically important for pool formation in the narrow alluvial valley, and would have contributed to formation of both pools and side channel habitats in the unconfined, low gradient reach.

5.2.1.6 Fish Habitat

The lower 27 miles of the North Santiam River from the mouth to Mehama contains gravel bars and riffles well suited for salmon spawning, although much of the gravel may be too large for spawning. Spawning activity in 1950 was mostly concentrated in the upper reaches of this section (Parkhurst et al. 1950). Upstream of this point to Big Cliff Dam the substrate is a mixture of boulder and "fair" to "good" quantities of gravel suitable for spawning. Approximately the lower 41 miles of the lower North Santiam and 15 miles of the Little North Santiam rivers are thought to have provided historic spawning habitat for spring chinook and steelhead, with steelhead habitat extending for most of the 86 miles of the mainstem North Santiam River (Fulton 1968, Fulton 1970). A 1940 survey recorded an average of 24.7 resting pools per mile below the location of the current dams, and 31.2 resting pools per mile above this location. Habitat availability in the vicinity of the Santiam Water Control District dams has been limited historically by low flows during the summer due to water diversions (McIntosh et al. 1995).

High summertime water temperatures have been a water quality problem in the North Santiam River since at least 1940. During a 1940 survey, summertime water temperatures ranged from 14.4 to 22.2°C in the North Santiam River downstream of the current location of the dams (McIntosh et al. 1995). Water temperatures were cooler upstream of this location and ranged from 7.8 to 12.8°C (McIntosh et al. 1995). Currently, the mainstem Santiam and the North Santiam rivers are both included on the ODEQ's 1998 303(b) list for high summertime water temperatures. Also included for summertime temperature violations are four tributaries to the North Santiam River including: Little North Santiam, Elkhorn, Boulder, and Blowout creeks (ODEQ 1998). Detroit Dam discharges during the summer are thought to delay upstream migration of adult spring chinook salmon and reduce juvenile salmonid growth rates because the released water is 5 to 8°C cooler than historically (ODFW 1990c). In the fall, this trend is reversed and the temperature of the released water is as much as 1 to 5°C warmer than stream temperatures (ODFW 1990c).

5.2.1.7 Fish Distribution

Prior to the construction of Detroit Dam, it was estimated that 71 percent of the North Santiam River spring chinook run spawned upstream of the dam site (Mattson 1948). This estimate was based only on observations of fish that had not been blocked further downstream at the Bennett Dam above the town of Stayton, the Mill City Diversion Dam, or the hatchery rack, and therefore was not based on the total population. It is unknown how these other blocks to migration affected the estimate of spawning habitat utilization above the dam site. The Santiam Water Control District dams have hindered migration of spring chinook and winter steelhead during low flows since at least 1940. In 1940, the runs of salmon and steelhead into the North Santiam had already fallen off considerably, and the depletion of the runs was noted to be partly due to the extensive barriers to migration and migration difficulties caused by the diversion of flows (McIntosh et al. 1995). Upstream migration of all salmonids are currently blocked at the Minto fish racks approximately 2.8 miles downstream of Big Cliff Dam.

Spring chinook salmon production occurred historically in the mainstem Santiam River, the North Santiam, the Little North Santiam and Breitenbush rivers, and Marion and Blowout creeks. Spring chinook currently spawn and rear in the North Santiam River between Stayton and the Minto fish rack, and the Little North Santiam up to Henline Creek (Olsen et al. 1992). Greatest spawning activity in the mainstem occurs in the ten miles below the Minto weir (Lindsay et al. 1999). The Marion Forks Hatchery, located above the Detroit Reservoir, rears spring chinook that are released as smolts downstream of the Minto fish rack. Hatchery spring chinook are released to mitigate for lost natural production resulting from dam construction and to increase recreational fishing opportunities.

Fall chinook salmon are not native to the North Santiam River subbasin, but natural production of hatchery fish (originating from hatchery releases) occurs in the mainstem Santiam River and the North Santiam River up to Valentine Creek (Olsen et al. 1992).

Winter steelhead are native to the North Santiam River subbasin. Hatchery winter steelhead have been released into the North Santiam River basin since 1952, but they are no longer stocked. Overall, the Santiam River subbasin presently produces about 60 percent of the wild steelhead in the Willamette River basin above Willamette Falls (Kostow 1995). Historically, natural winter steelhead production areas were located in the North Santiam and Little North Santiam rivers, and in Mad and Rock creeks (Olsen et al. 1992). Currently, winter steelhead can only access areas below Big Cliff Dam. Adult fish are not released above the dams to spawn naturally because neither dam has juvenile fish passage facilities.

Summer steelhead are not native to the North Santiam River subbasin, although hatchery summer steelhead have been released into the basin since 1966. Natural production occurs in the North Santiam River as a result of hatchery releases in the subbasin but is considered to be minimal (Olsen et al. 1992). Summer steelhead are currently collected at the Minto fish rack where they are either spawned or recycled downstream to increase the population that is subjected to angling.

Coho salmon are not native to the North Santiam River subbasin. Hatchery fish are known to spawn in the subbasin, but the status of a naturally producing run in the North Santiam River and its tributaries is unknown. The hatchery supplementation program in the Santiam River was discontinued after the 1985 brood release (Olsen et al. 1992). Fisheries managers believe the present distribution of coho in the subbasin to be minimal or nonexistent, although strays from nearby streams are found occasionally (ODFW 1990c).

Bull trout were present historically in the North Santiam River subbasin above the Little North Santiam River, but the last observation of a bull trout was in 1945. The population is considered to be "probably extinct" (Buchanan et al. 1997).

Oregon chub are known to exist currently in only five isolated populations within the North Santiam River subbasin (USFWS 1998a). These populations are all located downstream of the USACE dams. Historical records indicated the warm waters in the mainstem favored a resident fish population comprised of “rough fish such as chubs, squawfish, and suckers” (Parkhurst et al. 1950). The common name chub likely referred to a population comprising both chiselmouth (*Acrocheilus alutaceus*) and Oregon chub (McIntosh et al. 1995).

Big Cliff Reservoir and Detroit Reservoir support a variety of non-native warm water fishes as well as rainbow trout and native nongame fish. Detroit Reservoir also contains a population of kokanee, and residualized, land-locked chinook that resulted from three sources: juvenile salmon that became landlocked when the dam was completed in 1953, escapement of fish from the Marion Forks Hatchery, and fry and juvenile planting above the dam (Wetherbee 1962). Juvenile chinook continue to be stocked in Detroit Reservoir to benefit the recreational fishery (Hunt 1999).

The North Santiam River was reported to support good populations of cutthroat trout and rainbow trout (Willis et al. 1960). Kokanee salmon were first stocked in Detroit Reservoir in 1959 (Wetherbee 1965). Fish found in tributaries upstream of Detroit Reservoir include brook, cutthroat, rainbow, hybrid cutthroat-rainbow trout, sculpins, and dace (Ely 1981). An intensive trout population survey of Blowout Creek indicated that over 76 percent of the trout in the Blowout Creek basin were cutthroat trout, approximately 23 percent rainbow trout, and the remainder hybrid trout (Wetherbee and Hunt 1982). It was noted in the survey that cutthroat populations always extended upstream of rainbow trout. Rainbow trout were usually not found upstream of minor barriers, indicating that they probably originated downstream in either the mainstem of Blowout Creek or Detroit Reservoir. Cutthroat trout were found above presently impassable falls, but their upstream limit was usually at another barrier (Wetherbee and Hunt 1982). Cool water temperatures limit production of northern pikeminnows, largescale suckers, and redside shiners below Big Cliff Dam (USACE 1982).

5.2.2 South Santiam River

The South Santiam River is about 63 miles long and contains several major tributaries that historically or presently support listed species (Table 5-7). The lower 38 miles of the South Santiam River, below the Middle Santiam River, flows through relatively flat geography. The upper 25 miles of river lie in a narrow, forested canyon. The river is relatively broad where it transverses the valley floor, and narrow with deep pools throughout the upper canyon. Foster Dam was built at RM 38.5 on the South Santiam River in 1967. Green Peter Dam, built in the same year, is located on the Middle Santiam River approximately 6 miles above its confluence with the South Santiam River. Channel slopes upstream of Foster Dam and Green Peter Dam are moderately steep (0.4%) and the Middle Santiam River previously flowed through a narrow, forested canyon much of which has now been inundated by Foster and Green Peter reservoirs. The headwaters of both rivers are characterized by steep, forested drainages that originate on resistant young flow basalts and andesites and then flow through narrow valleys deeply incised through undifferentiated tuffaceous materials. These can range from easily erodible to highly resistant, and landslides are often common, particularly in basins that have experienced extensive timber harvest. The profile of the upper river generally reflects the transition from resistant volcanic basalts and tuffaceous deposits to easily eroded alluvial materials. The channel slope decreases to approximately 0.4 percent between Foster Dam and Lebanon, and decreases to less than 0.1 percent in the alluvial valley.

Table 5-7. Major streams of the South Santiam River subbasin with fish production potential (data compiled from Mattson 1948; Willis et al. 1960; Fulton 1968; Fulton 1970; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present Listed [1] Fish Species
Downstream of Foster Dam		
South Santiam River	38	OC, WSt, SCh, BT?
Thomas Creek	45	WSt, SCh
Crabtree Creek	43	WSt, SCh
Wiley Creek	16	WSt, SCh
Upstream of Foster Dam		
South Santiam River	23	WSt, SCh, BT
Canyon Creek	13	WSt, SCh?
Middle Santiam River	6	WSt, SCh
Upstream of Green Peter Dam		
Middle Santiam River	24	WSt, SCh
Quartzville Creek	26	WSt?, SCh

OC = Oregon chub • WSt = Winter steelhead • SCh = Spring chinook • BT = Bull trout

[1] Listed under the Federal Endangered Species Act.

Approximately 32 percent of the South Santiam River watershed is public land. The headwaters originate in the Willamette National Forest (ODFW 1990c). Quartzville Creek flows out of the Willamette National Forest and into the Middle Santiam above Green Peter Dam. Power generation at the Green Peter Dam results in large water level fluctuations in a short stretch of the Middle Santiam River. Foster Reservoir absorbs these fluctuations, and then the water is released evenly through the Foster power plant and into the South Santiam River. Lebanon Dam (which serves to divert water for municipal and other consumptive uses) on the South Santiam River below Foster Dam delays upstream passage of adult salmon. The canal associated with the dam has not been screened to prevent juvenile fish from entering the diversion, although the City of Albany is currently working on improvements to this system (Hunt 1999). Both Foster and Green Peter reservoirs have phytoplankton compositions similar to that of oligotrophic (nutrient poor) lakes in the Cascade Mountains (Altman et al. 1997).

5.2.2.1 Hydrology

The South Santiam River drains an area of approximately 1,000 square miles. Like the North Santiam River, streamflow in the basin reflects the same general seasonal distribution as the mainstem Willamette, with the majority of runoff occurring during the winter and low flows during July and August. Because the headwater elevations are somewhat lower than in the North Santiam River, the South Santiam River does not exhibit as pronounced a bimodal peak resulting from spring snowmelt. Flows in the lower South Santiam River have been controlled by Green Peter Dam and Foster Dam since 1966. Green Peter is the primary flood control dam, regulating runoff from 227 square miles of the upper South Santiam River basin. Foster Dam provides some additional runoff storage, and reregulates flow released from Green Peter Dam for power generation.

Flood control operations at Green Peter and Foster dams have substantially decreased the magnitude and frequency of extreme high flow events in the lower river. The highest flow recorded on the South Santiam River prior to dam construction was 95,200 cfs in December 1964, with flows greater than 50,000 cfs common (USGS 1997). Since construction of the projects, the two year recurrence interval event has decreased from about 37,900 cfs to about 15,800 cfs, and no flows greater than 29,300 cfs have occurred (see Appendix F). The two major unregulated tributaries below Foster Dam, Crabtree and Thomas creeks, enter the South Santiam River just upstream of the confluence with the North Santiam River.

As noted above, flows in the South Santiam River are naturally lowest in the late summer and early fall. The average daily flow in August prior to dam construction was 261 cfs (Moffatt et al. 1990). Since construction, no flows lower than 428 cfs have been recorded at the Waterloo gage and the average daily flow in August has increased to 816 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically, because storage is available at USACE facilities to redistribute flood volumes and release water later in the year for flow augmentation purposes.

Although there is some flow diversion upstream of Waterloo (USGS 1997), the primary diversion is the Lebanon Santiam Canal located downstream of the Waterloo gage. The Lebanon canal continuously diverts between 25 and 200 cfs from the South Santiam River at Lebanon (USGS data). In addition, the Albany canal diverts water from the South Santiam River at Lebanon, with return flow reaching the Willamette River near Albany.

5.2.2.2 Sediment Transport

Construction of Foster and Green Peter dams blocked transport of sediment supplied from approximately 50 percent of the South Santiam River subbasin. The area blocked likely contributed an even larger proportion of the total basin sediment load because of steeper slopes and higher sediment transport rates than in downstream areas. Downstream of the dams, the South Santiam River currently receives sediment from Wiley, McDowell, Crabtree and Thomas creeks.

Overall, there is little documentation available regarding the effects of dam construction on sediment transport in the South Santiam River. All sediment from upstream reaches is trapped behind the dams. However, the sediment transport capacity has been substantially reduced within this reach because maximum flows are less than the pre-dam two-year return interval event. Since there are still a number of tributaries contributing sediment and the channel has a relatively low gradient below Foster Dam, the expected response would be aggradation at tributary junctions as a result of the substantially reduced transport capacity (Table 5-3).

Surveys of the South Santiam River downstream of Foster Dam indicated that gravel was the predominant substrate in 1959 (Willis et al. 1960). Analysis of gage rating curves at Waterloo, 13.7 miles downstream of Foster Dam depicted constant conditions over the period from 1935 to 1965 (Klingeman 1973). However, the dams did not influence flows or sediment transport on the South Santiam River during that study period because they were not yet completed. It is likely that reaches below Foster Dam will be more armored and could incise over the long term. However, the reach of the Middle Santiam River between Green Peter Dam and Foster Reservoir is relatively short and may not exhibit substantial future downcutting because of the stronger flood control influence of Green Peter Reservoir and the historic boulder and bedrock substrate there (McIntosh et al. 1995).

5.2.2.3 Bank Protection and Channelization

The South Santiam River channel downstream of Foster Dam was described in 1947 as being extremely sinuous divided by large islands in many places. Streambanks in many areas were unstable and actively eroding. Approximately 26 miles of levees with a mean height of seven feet were estimated as being required to provide adequate channel capacity for controlled flood discharges released from Foster and Green Peter dams. However, the cost required to construct the structures exceeded the benefits and the projects were assigned a low priority (USACE 1947). As of 1989, more than 15 miles of channel bank in the lower South Santiam River had been protected by rip-rap or revetments, such that more than 35 percent of the channel downstream of RM 19 has artificial banks (USACE 1989d).

5.2.2.4 Floodplain Maintenance and Side Channel Connectivity

Absent specific studies, it is likely that reduction in flood flows, sediment supply, and LWD, construction of extensive levees and revetments have all probably contributed to a reduction in habitat complexity and floodplain function in the alluvial portion of the South Santiam River below RM 37, as has been observed elsewhere in the Willamette system (EA 1991a; Minear 1994; Benner and Sedell 1997). However, the extent to which this has occurred is presently unknown.

5.2.2.5 Large Woody Debris Transport

There is little information available on pre- and post-dam LWD loadings in the South Santiam River. Like sediments, LWD that was formerly transported downstream from forested headwaters is now trapped behind the dams. Log drives and removal of wood for navigation and flood control purposes were common practices historically on Oregon rivers (Sedell and Froggatt 1984). These practices, coupled with prevention of downstream transport by the dams, have probably resulted in an overall decline in the amount of in-channel LWD found within the South Santiam River. Agricultural development in the alluvial valley has also resulted in the loss of riparian forest communities.

The effects of reduced LWD loading are likely to have been most pronounced in the alluvial reaches found in the lower South Santiam River. LWD was probably historically important for forming pools and side channel habitats in the unconfined, low gradient reach downstream of Foster Dam.

5.2.2.6 Fish Habitat

In general, substrate in the South Santiam River is comprised of larger particles and contains more bedrock than in the North Santiam River. Substrate in the lower 38 miles of river is predominantly gravel, some of which is suitable for salmon spawning. The substrate in the canyon reach is predominated by boulders and bedrock with only about 5 miles of river containing a good quantity of spawning area. However, considerable spawning area is provided by frequent small patches and occasional larger areas of small gravel (USACE 1962). Although most of the historical anadromous salmonid spawning was in the lower 24 miles of the Middle Santiam River and the lower reaches of Quartzville Creek (Willis et al. 1960), approximately 43 miles of the South Santiam River and lower Wiley Creek (approximately 500 yards downstream of Foster Dam) also provided spring chinook spawning habitat; steelhead spawned in the upper South Santiam River (Fulton 1968, Fulton 1970). Other tributaries to the Middle Santiam River have been considered to be small and relatively unimportant for salmon production (USACE 1962). Steelhead also spawn in Thomas, Crabtree, and Canyon creeks, tributaries to the South Santiam River (Fulton 1970).

A 1979 survey indicated that tributaries to the South Santiam River contain a wide variety of habitats ranging from streams cascading down steep gradients with medium sized boulders present to streams with numerous pools and riffles. Substrates include cobble, gravel, and large boulders. Crabtree Creek was found to contain good salmonid habitat in its headwaters, and juvenile steelhead were captured in the South Fork Crabtree Creek and in Bald Peter Creek. Many of the upper tributaries of the Middle Fork had steep gradients and short pools cascading over medium boulders with little habitat available for salmonid production (Ely 1981).

The South Santiam River was historically highly polluted. A 1940 survey noted the influence of chemical waste from a paper mill and sewage from the city of Lebanon that extended from the mouth of the river to approximately RM 19 (1 mile below the Lebanon bridge) (McIntosh et al. 1995). Many dead fish were observed and the bottom rubble was covered with a thick gelatinous substance. Additionally, the paper mill diverted almost all of the river flow at some times of the year. A survey of obstructions, diversions, and pollution problems conducted in 1960 recorded one diversion ditch and effluent from a paper mill. Currently, the primary water quality concern in the South and Middle Santiam river system is high summer water temperatures. The ODEQ's 1998 303(d) list included six reaches with summer temperature violations including: the mainstem South Santiam River from McDowell Creek to the mouth, and McDowell, Crabtree, Hamilton, Quartzville, and Thomas creeks. Additionally, the mainstem South Santiam River from McDowell Creek to the mouth was listed for high levels of bacteria (ODEQ 1998).

Water temperatures in the South Santiam River commonly exceed 23.9°C in summer months (ODFW 1990c). Elevated summer water temperatures in the South Santiam River were also a historical problem, primarily caused by low flows as a result of numerous water diversions for irrigation, industrial, and domestic uses (Parkhurst et al. 1950). In lower Thomas and Crabtree creeks, water temperatures also commonly exceed 21.1°C. This may prevent many species and stocks of anadromous salmonids from holding and rearing in these reaches (ODFW 1990c). High water temperatures in Quartzville Creek have been attributed to the lack of riparian vegetation (Skeesick and Jones 1988). Overall, within the national forest, an estimated 10.1 miles of stream lack sufficient riparian vegetation for shade (Skeesick and Jones 1988).

Although not specified explicitly on the 303(d) list, elevated levels of turbidity in the South Santiam River are believed to result from accelerated bank and channel erosion associated with agricultural practices such as removal of riparian vegetation and livestock grazing (ODFW 1990c). Additionally, elevated erosion and sediment production in the Willamette National Forest contributes to high turbidity in the system (ODFW 1990c).

Recent gold mining in the drainage could impact trout spawning from dredging and subsequent siltation (Skeesick and Jones 1988). Spawning habitat in the Middle Santiam River has also been influenced by checkerboard logging (Skeesick and Jones 1988). Areas of extensive logging damage were observed in 1979 in streams with salmonids present (Ely 1981).

5.2.2.7 Fish Distribution

Green Peter Dam is located on the Middle Santiam River at approximately RM 5.5, and at full-pool elevation the reservoir inundates approximately 10 miles of the Middle Santiam River, 5 miles of Quartzville Creek, and the lower reaches of several smaller tributaries (USFWS 1961). Construction of Foster Dam inundated nearly eight miles of the South Santiam River and Middle Santiam River combined. The upper limit to spring chinook and steelhead distributions on the South Santiam River is at a waterfall located at RM 63, approximately 1.2 miles above Soda Fork and just below the mouth of Elk Creek (Hunt 1999).

Spring chinook salmon production in the South Santiam River subbasin occurred historically in predominantly the Middle Santiam River, Quartzville Creek, and a 5-mile reach upstream of Cascadia on the South Santiam River. Mattson (1948) estimated that 50 percent of the Middle Santiam River spring chinook run spawned upstream of Green Peter Dam; the USFWS (1961) estimated 40 percent. Mattson (1948) estimated that 85 percent of the entire South Santiam River spring chinook run, including the Middle Santiam River, spawned upstream of Foster Dam prior to construction. An estimated annual run of 1,000 spring chinook entered the Middle Santiam River prior to dam construction (USFWS 1961). Until recently, adults were released into the upper South Santiam River but were not allowed to pass above Green Peter Dam. This management action was designed to keep the water supply used by the South Santiam Hatchery free of diseases that may infect returning adults. Hatchery spring chinook are released to mitigate for lost natural production resulting from dam construction and to increase recreational fishing opportunities. Spring chinook currently spawn and rear in the South Santiam River from

Ames Creek to Foster Dam, Thomas Creek from Jordan Creek to Hall Creek, Crabtree Creek from RM 14 to White Rock Creek, and in Wiley Creek. Most spawning activity in 1998 below Foster Dam occurred upstream of Waterloo to the dam (Lindsay et al. 1999).

Fall chinook salmon reproduce naturally in the system, but originate from hatchery releases. Spawning occurs in the South Santiam River up to Hamilton Creek, Shelton Ditch, and the Salem Canal (Olsen et al. 1992).

Winter steelhead trout are native to the South Santiam River subbasin. Historically, natural winter steelhead production areas above this site were located in the upper mainstem of the South Santiam, and in Thomas, Crabtree, McDowell, Wiley, Canyon, Moose, and Soda Fork creeks. The Middle Santiam River and Quartzville Creek also provided spawning areas (ODFW 1990c). Currently, Moose and Canyon creeks are important tributaries to the South Santiam River for natural spawning above Foster Dam. The land surrounding Moose Creek was logged recently, with unknown future effects on salmon habitat. Before construction of Foster Dam, an estimated 2,600 winter steelhead spawned upstream of the dam site (Buchanan et al. 1993). Natural production in the South Santiam River from fish released above Foster Dam has declined (ODFW 1990c). Hatchery winter steelhead were stocked in the basin from 1952 until recently when the practice was discontinued to avoid further genetic effects on the native runs. Adult winter steelhead are currently not passed above Green Peter Dam and into the Middle Santiam River because of unsuccessful downstream passage past the dam, and only native winter steelhead are allowed upstream of Foster Dam to spawn naturally in the South Santiam River.

Summer steelhead are not native to the South Santiam River subbasin. Natural production in the South Santiam River and in Hamilton, McDowell, and Wiley creeks occurs as a result of hatchery releases in the subbasin, but is considered to be minimal (Olsen et al. 1992).

Coho salmon are not native to the South Santiam River subbasin. Hatchery fish are known to spawn in the subbasin, but the status of a naturally producing run in the South Santiam River is unknown. Hatchery supplementation was discontinued after the 1985 brood release (Olsen et al. 1992).

Bull trout were historically present in the South Santiam River above Foster Dam, but the last observation of a bull trout was in 1953. The population is considered to be "probably extinct" (Buchanan et al. 1997).

Oregon chub are not known to exist currently in the South Santiam River subbasin (Scheerer et al. 1998). However, historical records indicate that the basin contained abundant “chubs” (McIntosh et al. 1995), which could have referred to a population comprising both chiselmouth and Oregon chub.

Sockeye salmon were introduced into Green Peter Reservoir in 1967 and 1968 (Olsen et al. 1992). Hatchery sockeye are no longer released but are believed to have residualized in the reservoir and contribute, along with hatchery kokanee salmon releases, to the sport fishery using the reservoir (Olsen et al. 1992).

Resident fish in the South Santiam River system include rainbow and cutthroat trout and mountain whitefish. Foster and Green Peter reservoirs support a variety of non-native warm water fish species in addition to native nongame fish including northern pikeminnow, largescale suckers, and redside shiners (USACE 1982). Tributaries upstream of Foster Reservoir and Green Peter Reservoir also contain brook trout, sculpin, dace, and brook lamprey (Ely 1981; USACE 1982).

5.3 MCKENZIE RIVER

The McKenzie River originates on the western slopes of the Cascade Range and flows westward for approximately 90 miles before it joins the Willamette River a few miles downstream of the city of Eugene, Oregon, at RM 176. The system contains extensive habitat for spring chinook salmon and bull trout (Table 5-8). Much of the McKenzie River subbasin is mountainous with steep ridges and a narrow band of level land in the valleys along the McKenzie and Mohawk rivers. Although the mainstems of the McKenzie and Mohawk rivers have relatively low gradients, most of the other tributaries have steep gradients in their upper reaches (ODFW 1990e). The headwaters of the McKenzie River are characterized by a broad, gently sloping volcanic ridge that extends west from the steep peaks of the Three Sisters. Vast areas of porous lava in the Cascade Range above the headwaters of the river system retard surface runoff and act as a reservoir for large, relatively constant-flowing springs. This phenomenon helps stabilize flows and temperatures to a large extent, in this river (Willis et al. 1960). Lava flows frequently blocked the river long ago, forming numerous deep lakes and springs. Downstream of RM 70, the river follows a fault for about 7 miles before entering the highly dissected landscape of the older Western Cascades formations (Minear 1994). There, the river has incised deeply through a complex mixture of undifferentiated tuffaceous sedimentary rocks, tuffs and basalt (Walker and MacLeod 1991).

Table 5-8. Major streams of the McKenzie River subbasin, Oregon with fish production potential (data compiled from Mattson 1948; Willis et al. 1960; Fulton 1968; Fulton 1970; USFS 1994; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present Listed Fish Species [1]
Mainstem McKenzie River		
McKenzie River	81	SCh, BT
Mohawk River	26	SCh, WSt
Gate Creek	10	SCh
Quartz Creek	12	SCh?
Horse Creek	22	SCh, BT
Separation Creek	13	SCh?, BT
Lost Creek	4	SCh
Olallie Creek	2	BT
Anderson Creek	2.5	BT
Downstream of Cougar Dam		
South Fork McKenzie River	4.5	SCh, BT
Upstream of Cougar Dam		
South Fork McKenzie River	25	SCh, BT
French Pete Creek	11	SCh?, BT
Augusta Creek	2	SCh?
Roaring River	2	BT
Downstream of Blue River Dam		
Blue River	1.8	SCh, BT
Upstream of Blue River Dam		
Blue River	14	SCh
Lookout Creek	3	SCh?

SCh = Spring chinook • WSt = Winter steelhead • BT = Bull trout

[1] Listed under the Federal Endangered Species Act.

Glaciation has also influenced the landforms of the McKenzie River subbasin. The extent of the most recent glacial advances are marked by the Lost River Moraine downstream of Belknap Springs; earlier glacial advances extended farther down the valley to Blue River (Minear 1994). Glacial deposits fill the McKenzie valley where it widens out in the vicinity of Blue River (Walker and MacLeod 1991).

The profile of the upper river generally reflects the transition from resistant volcanic parent material through the more easily erodible tuffaceous sedimentary rock and glacial landforms. The channel slope decreases from 1.2 percent upstream of Belknap Springs to less than 0.4 percent through the glacial valley just upriver of Blue River. Downstream of Blue River the channel slope remains between 0.2 to 0.4 percent, but the channel is tightly confined within a narrow canyon for approximately 20 miles. The slope flattens abruptly to less than 0.2 percent as the river enters the wide Willamette Valley.

About 70 percent of the McKenzie River subbasin is comprised of federal land managed by the USFS and BLM for timber production, wilderness areas, and other uses. The remaining area is largely privately owned (ODFW 1990e). The area is used extensively for recreational purposes, and the McKenzie River is one of the most popular rivers for fishing and boating in Oregon (ODFW 1990e).

Fish habitat in the 18 miles below the Eugene Water and Electric Board's (EWEB) 22-foot high Leaburg Dam located at RM 39 is influenced by flow diversions used to generate electricity (ODFW 1990e; USACE 1995a). The lengths of river directly affected by the Leaburg and Walterville projects have been estimated to be 5.8 miles and 7.3 miles, respectively, with an approximately 5 mile long undeveloped reach in between (T. Downey EWEB, personal communication, February 2000). The Leaburg Dam has two fish ladders, but only one ladder is operational. The 57-acre impoundment from this dam extends 1.5 miles upstream. The 5-mile long, unlined Leaburg diversion canal is now screened for juvenile fish and contains a bypass system to channel the juvenile fish back to the McKenzie River just below the Leaburg Dam. Recent changes to the EWEB's canal operations have allowed more water to remain in the mainstem McKenzie for fish. The EWEB's Walterville project located at RM 21, consists of an unscreened headgate, a 4-mile long unlined canal, a 345 acre-foot pumped impoundment pond used for power peaking, and a 16.5 foot-square penstock that leads to a single turbine. The water exits the turbine and enters a 2-mile long tailrace that leads back to the McKenzie River. A fish rack prevents adults from moving up the tailrace; a bypass channel allows adults stopped by the rack to return to the mainstem McKenzie. EWEB also operates two dams on the upper McKenzie River (Trail Bridge and Carmen dams), and one dam (Smith River Dam) near the headwaters. The Trail Bridge-Carmen complex was completed in 1963, the same year as Cougar Dam.

Cougar and Blue River dams have altered the flow and temperature regimes of the South Fork McKenzie and Blue rivers. Flow and temperature in the mainstem McKenzie River below the projects have been altered, albeit to a lesser extent. In general, the projects have reversed natural flow and temperature patterns in the South Fork McKenzie and Blue rivers during spring through fall (ODFW 1990e). Flows and temperatures below the two dams are decreased in the spring and summer when the reservoirs are filled, and increased in the late summer and fall during drawdown (ODFW 1990e).

Cougar Reservoir shoreline slopes are steep with relatively little flat land adjacent to the water. Annual drawdown for flood control, coupled with operation at full pool during summer has precluded riparian development along the periphery of Cougar Reservoir. Lowering of the pool has exposed denuded rock areas and banks of gravel and mud. The lack of riparian habitat limits the presence of aquatic furbearers, amphibians, and birds normally associated with lakeshore areas.

5.3.1 Hydrology

The McKenzie River drains an area of approximately 1,300 square miles. The majority of runoff occurs during the winter; flows are lowest during July, August and September. Gages in the upper basin exhibit a pronounced bimodal peak resulting from winter runoff and spring snowmelt.

Flood flows on the McKenzie River have been controlled by Cougar and Blue River dams since 1963. There are a number of other dams operated for power production that also influence flows in the McKenzie River basin, including Leaburg Dam located on the mainstem McKenzie downstream of the Cougar and Blue River projects, and the EWEB Carmen-Trail Bridge complex located upstream. The combined operations of these projects has substantially decreased the magnitude and frequency of extreme high flow events in the lower river, although the influence of the Carmen-Trail Bridge complex is small relative to the USACE projects because they are operated essentially as run-of-the-river projects (T. Downey, EWEB, personal communication, February 2000). Prior to dam construction, the highest flow recorded on the McKenzie River at Vida was 64,400 cfs in December 1945 with flows greater than 40,000 cfs were not uncommon (USGS 1997). Since construction of the projects, the two-year recurrence interval event at Vida has decreased from about 29,200 cfs to about 17,500 cfs; no flows greater than about 35,000 cfs have occurred (see Appendix F).

In general, seasonal flow variations in the McKenzie River are less than in other Willamette River basin tributaries because of the abundance of springs and lakes in the upper basin. As noted above, flows are naturally lowest in the late summer and early fall. The average daily flow in September prior to construction of the Cougar and Blue River dams was 2,030 cfs. Since construction of the projects, the average daily flow in September has increased to 2,956 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically, because storage is available at USACE facilities to redistribute flood volumes and release water later in the year for flow augmentation purposes. There are no flow diversions upstream of Vida (USGS 1997).

5.3.2 Sediment Transport

Leaburg Dam initially blocked the downstream transport of sediment in the lower McKenzie River when it was constructed in 1929. It has since filled in and passes gravel to spawning areas located downstream (T. Downey, EWEB, personal communication, February 2000). There are also five dams in the upper basin, including Blue River and Cougar dams, and these dams alter the hydrology and trap sediment from over 35 percent of the watershed. Construction of Blue River and Cougar dams reduced the area supplying sediment to the mainstem McKenzie River by 23 percent. The change in peak flows resulting from flood control by Cougar and Blue River dams has reduced the river's ability to transport sediment. Prior to dam construction, peak flows with a five-year recurrence interval at the Vida gage were able to move sediments up to 150 mm in diameter, the estimated historic median particle size (Minear 1994). After dam construction, the peak flow corresponding to a five-year return interval was reduced from over 40,000 cfs to about 22,000 cfs; this flow is no longer capable of mobilizing the median substrate particle size (150 mm) (Minear 1994). A comparison of visual substrate estimates from 1937-38 and 1991 suggest that the amount of substrate larger than 150 mm has increased from 56 percent to 76 percent in area (Minear 1994).

Reduced peak flows and reduced sediment inputs have probably contributed to the decrease in gravel bar areas downstream of the South Fork McKenzie River, as vegetation has become established on surfaces that were formerly regularly inundated. Dramatic changes have occurred in channel configuration and the area of exposed gravel bars in the wide, low gradient valley downstream of the South Fork McKenzie River. However, the impact of reduced flood flows and sediment supply is confounded by concurrent harvest of riparian vegetation and subsequent regrowth (Minear 1994).

A reduction in the total area of gravel bars was also noted in the canyon reach downstream of the confluence with Blue River, although the number of side channels increased (Minear 1994). These changes suggest that establishment of vegetation on formerly unstable bar surfaces may be a more important agent of channel change than a loss of in-channel sediment storage in the McKenzie system. This is consistent with the theoretical response to a large reduction in flows combined with a moderate reduction in sediment supply (Table 5-3)

Since Cougar and Blue River dams are located on tributary streams rather than on the mainstem, sediment supplied by the majority of the basin is still routed downstream through reaches influenced by these dams. Thus, the effects of armoring are not expected to be as severe as in basins where dams block the mainstem, except within the reaches of Blue River, South Fork McKenzie River, and upper mainstem McKenzie River immediately downstream of the dams.

The lower, unconfined section of the McKenzie River downstream of Leaburg Dam historically contained frequent, mid-channel bars and islands, and multiple channels that periodically shifted from one side of the river to the other. Bed shear stress was high because the river gradient was still steep relative to discharge, and high flows were capable of transporting sediment larger than 256 mm in diameter. The river is believed to have had an armored cobble bed within this reach historically, although there was substantial hydraulic roughness causing deposition of finer gravel and sand (EA 1991a).

The effects of reduced sediment supply resulting from construction of Cougar and Blue River dams may not extend past Leaburg Dam at RM 40.6. There is evidence of discontinuous downcutting of one to five feet in the lower McKenzie River, but there is little evidence that construction of Leaburg Dam has resulted in significant bed degradation downstream (EA 1991a). There has been a significant decrease in the elevation of the USGS gage near Coburg; approximately 3 feet over the period from 1945 to 1965, and an additional 3 feet between 1965 and 1973 (Klingeman 1973). A number of factors were identified as potential causes of the downcutting near Coburg, including removal of a series of pilings located downstream of the gage, as well as a large, in-stream sand and gravel removal operation located approximately one-half mile downstream of the pilings.

Over the entire reach of the McKenzie River below Leaburg Dam, the effects of reduced peak flows and construction of flood control structures (levees and revetments) are believed to have had a greater influence on channel morphology than reduced sediment supply. Such effects and actions would serve to prevent flows capable of creating new bars and islands, constrict the channel, prevent bank erosion, and allow encroachment of perennial vegetation on formerly active bar surfaces (EA 1991a).

5.3.3 Bank Protection and Channelization

To provide protection from flooding, the USACE recommended in 1947 that nearly continuous levees with an average height of 7 feet be constructed along the lower McKenzie River downstream of RM 22 (USACE 1947). As of 1990, more than 11 miles of streambanks in the lower McKenzie River were protected by rip-rap or revetments (USACE 1989d). These are located primarily along the outside of meander bends, and are concentrated in the heavily populated valley near the confluence with the Willamette River (EA 1991a). There are no levees or revetments constructed or maintained by the USACE in the vicinity of Blue River and the South Fork McKenzie River.

Rip-rap banks retard or prevent the formation of mid-channel bars and islands in the McKenzie River that are normally created and maintained by bank erosion and recruitment of sediment from streambanks. As a result, the channel form has been simplified and the bed has become comprised of an increasingly homogenous mixture of cobbles with few gravel deposits present. The dominant particle size is 152 mm and the D_{50} is 119 mm, sizes approaching the maximum size utilized by spawning salmon and steelhead (EA 1991a).

5.3.4 Floodplain Maintenance and Side Channel Connectivity

Lateral channel migration and avulsions in unconfined channels such as the reaches near the confluence with the South Fork McKenzie River and downstream of Leaburg Dam generally maintain a mixture of stand ages in the riparian zone, and form and maintain off-channel habitat. Reduction in peak flows capable of forming and maintaining gravel bars and side channels, and confinement, narrowing and reduced sediment supply resulting from entrapment of gravel behind dams, bank protection and vegetation encroachment, have contributed to a reduction in floodplain function and connectivity in the McKenzie River. The length of side channels in the unconfined reach downstream of the confluence with the South Fork McKenzie River decreased from almost 6,000 feet in 1946 to just over 3,000 feet in 1986 (Minear 1994). The area of gravel bars also decreased during this same time period, from over 30 acres to 3 acres. These data suggest that the main channels in these reaches are downcutting and disconnecting from side channel habitats. The effects would likely continue until an armor layer develops; there is presently no indication as to whether this has occurred.

The reach downstream of Leaburg Dam has been responding to a similar reduction in sediment supply for a longer time period. The area of islands and length of stream margin habitat decreased from approximately 540 acres and 117,000 linear feet respectively in 1930, to approximately 270 acres and 95,000 linear feet in 1990 (EA 1991a). The area of off-channel sloughs increased from approximately 39 acres in 1930, to 51 acres in 1990. However, this increase is considered temporary because sloughs are created in former side channels as they become disconnected from the mainstem and fill in over time (EA 1991a).

Riparian communities may also be influenced by the reduction in large floods that formerly inundated the floodplain. Such floods recharge the water table and groundwater storage contributing to summer flow. The amount of riparian habitat adjacent to the lower McKenzie River is estimated to have been reduced from 1,607 acres in the 1930s to less than 930 acres, most likely because of land use. No changes in the composition of floodplain vegetation communities were noted as of 1990. However, it has been hypothesized that a drop in water table elevation would curtail opportunities for natural regeneration of cottonwood forests on newly formed bar surfaces and facilitate replacement of native cottonwood forests with coniferous species such as Douglas-fir that are less tolerant of wet conditions, which could influence future riparian community composition (EA 1991b).

5.3.5 Large Woody Debris Transport

Construction of Cougar and Blue River dams disrupted the downstream transport of LWD to downstream reaches. Wood and organic material trapped behind the dams would have eventually been transported to the McKenzie River. As evidence, the amount of LWD in the McKenzie River between the confluence with the South Fork McKenzie and Leaburg Dam decreased from twelve large aggregations and three large single logs in 1930, to four aggregations and one large single log in 1991 (Minear 1994).

The influence of dams disrupting the downstream transport of LWD relative to other land use activities in the McKenzie River basin is presumed to be less severe than in other basins with dams located on the mainstems; the river still routes wood from unregulated tributaries. However, in the past it was common practice for landowners and river guides to remove LWD from the channel for flood control and navigation purposes or to sell marketable wood (Minear 1994). Much of the in-channel LWD in the mainstem near the confluence with the South Fork was removed during intensive logging of the riparian area in the 1950s. The relatively young, existing riparian stands and the disruption of downstream LWD transport by Cougar and Blue River dams will probably continue to depress LWD recruitment rates to the lower McKenzie

River. The loss of LWD is thought to be one of the primary factors influencing the reduction in large pool habitat in the McKenzie River (Minear 1994).

5.3.6 Fish Habitat

Substrate suitable for salmonid spawning occurs primarily in the lower 55 miles of the McKenzie River, in Horse Creek, and in the South Fork McKenzie River. These streams historically contained the most important spring chinook spawning grounds in the subbasin (McIntosh et al. 1995). In 1946-1947, spring chinook primarily spawned in the mainstem McKenzie River near the Hayden, Coburg, and Hendrick's bridges. Fish were also located in large numbers at Wilson's Bend near the mouth and the lower section of the Walterville Canal because of the presence of a rack placed in the river to collect fish for hatchery production (Mattson 1948).

Several tributaries in the subbasin are susceptible to landslides and debris torrents due to steep slopes, heavy rainfall, unstable soils, and timber harvest and road construction (ODFW 1990e). Torrents in tributaries have impacted fish habitat by scouring channels, depositing large amounts of sediment and debris, and increasing turbidity (ODFW 1990e). In 1981, 13.5 miles of stream in this watershed had insufficient shade due to clear cuts (Skeesick and Jones 1988). The smaller tributaries are predominantly steep with relatively little habitat or access for migratory fish. Several larger tributaries contain large wood that provide habitat and sediment storage. Many tributaries contain small populations of resident cutthroat trout; some tributaries to Cougar Reservoir contain redside shiners in their lower reaches (USFS 1994).

The Blue River was surveyed in 1937 for salmon spawning habitat and was found to contain very little spawning area (McIntosh et al. 1995). The watershed of the Blue River consists of high hills that increase to mountains in the headwaters. The river is characterized by the predominance of bedrock and large rubble, substrates, scarce riffles, and large pools (McIntosh et al. 1995). Summer water temperatures above the reservoir are warm relative to temperatures in the South Fork McKenzie River and to bull trout habitat requirements (Section 6.1.2).

Sedell et al. (1992) found that the quantity and quality of anadromous salmonid spawning habitat was good in the upper McKenzie River basin and that existing conditions have not changed substantially from historical. Available spawning gravel has far exceeded the abundance of spring chinook spawners, and less than 1 percent of available spawning gravel was used during the period 1965 through 1991 (USACE 1995a). Neither spawning nor rearing habitat quantities appear to be currently limiting spring chinook productivity in the McKenzie River basin.

Bull trout spawning habitat appears to be distributed throughout the system in limited quantities and in part reflects water quality. The Roaring River constitutes the primary, known spawning habitat in the South Fork McKenzie River drainage, and contains pocket spawning habitat. The mainstem McKenzie River population is known to spawn primarily in Anderson and Olallie creeks, which are spring-fed and contain relatively large amounts of gravel and small cobble. The upper McKenzie River population spawns in the mainstem in areas potentially influenced by groundwater inputs. Sweetwater Creek, tributary to Trail Bridge Reservoir, contains potential spawning habitat, but it does not appear to have been used yet since reintroduction efforts began. Shallow, slower water rearing habitat for bull trout is limited in extent in the mainstem McKenzie River, which may limit mainstem recruitment of young fish originating in Anderson and Olallie creeks. Both tributaries contain suitable rearing habitat and relatively large densities of juveniles. Observations of fry emigrations to the mainstem McKenzie River from Anderson Creek may indicate population levels in the tributary are near carrying capacity (Buchanan et al. 1997; Unthank 1998, 1999).

A 1937 and 1938 survey of the mainstem McKenzie River did not report any water pollution problems in the river. Nine reaches in the basin are currently listed on ODEQ's 303(d) list for elevated summer-time temperatures (ODEQ 1998). The production of aquatic insects in the McKenzie River basin is considered to be abundant and diverse (USFS 1994).

5.3.7 Fish Distribution

Fish distributions in the McKenzie River system were influenced by human activities well before USACE facilities were constructed on the Blue River and the South Fork McKenzie River. One of the historical obstructions to fish migration included a fish hatchery rack on the McKenzie River (operated by the state) that was located approximately 18 miles upstream of the mouth and downstream of both the Blue River and the South Fork McKenzie River. This rack intercepted the entire spring salmon run, and was operated from 1902 through 1957. Fish spawned from these racks were used for stocking the McKenzie River system, as well as other sites in Oregon and other states (ODFW 1990e). A historical documentary reported that until 1921, the management policy was to transfer most, or all of the eggs out of the basin (Cone and Ridlington 1996). Adult passage of a portion of the population was allowed upstream past the rack starting in 1954, after a major decline in the spring chinook runs was noted. Habitat surveys conducted during 1937 and 1938 noted that Vida Dam, operated by Eugene Power Supply at approximately RM 31, was not believed to prevent fish passage (McIntosh et al. 1995). The only other obstruction to fish passage in the McKenzie River prior to construction of the Cougar and Blue River projects was a natural one, at Tamolitch Falls, located near RM 78 (Skeesick and Jones

1988). Construction of Trail Bridge Dam below Tamolitch Falls prevented upstream migration of anadromous and resident species. Bull trout have been caught in Carmen Reservoir (Goetz 1994), suggesting a historical presence above Tamolitch Falls, as well.

Spring chinook salmon are native to the McKenzie River basin. The McKenzie River subbasin is considered to be the most important remaining area for natural production of spring chinook in the Willamette River basin (ODFW 1999a). Spawning activity in 1998 occurred upstream of Hendricks Bridge, which is located at RM 20 (Lindsay 1999). The ODFW lists the McKenzie River as essential habitat for spring chinook salmon production in the Willamette River basin (ODFW 1993). The McKenzie River system produced an estimated 39 percent of the run of spring chinook above Willamette Falls in 1947, prior to the construction of major dams on Willamette tributaries, (Mattson 1948); in 1959 it accounted for about 50 percent of the run (ODFW 1990e).

Prior to construction of Cougar Dam, approximately 25 miles of mainstem South Fork McKenzie River were accessible to spring chinook. Only 2 percent of the McKenzie River spring chinook population were estimated to use the South Fork in the late 1940s (Mattson 1948). This estimate was based on observations of spring chinook allowed to pass upstream of the hatchery rack placed on the mainstem McKenzie (965 salmon passed upstream and 1,105 were used for egg collection) (Mattson 1948). Currently, only 4.5 miles of the mainstem below the dam are accessible (USFS 1994).

Construction of Blue River Dam resulted in minor losses of spring chinook spawning habitat (ODFW 1990e). Currently, the reach below the dam provides some habitat for spring chinook spawning and rearing (ODFW 1990e). The watershed above the dam does not have significant habitat for bull trout, which are not believed to be currently present in the area (USFS 1998). Chinook salmon originating from previous releases appear to have residualized in Blue River and Cougar reservoirs (J. Ziller, ODFW, personal communication, August 1999).

Fall chinook salmon are not native to the McKenzie River and were introduced into the McKenzie and Mohawk rivers from 1966 through 1968. Fish were place in the Willamette River near the mouth of the McKenzie River until 1987 (ODFW 1990e).

Winter steelhead trout are not known to have used the system historically (USFWS 1948; Fulton 1970; ODFW 1990e). This is believed to be due to unidentified reasons that appear to limit the ability of the system to produce steelhead, even though resident trout and chinook salmon have been successful there (64 FR 14517). Winter steelhead were introduced into the system beginning in 1956 (Fulton 1970). Currently, winter steelhead are found predominantly in the Mohawk River (Hutchison et al. 1966b; Fulton 1970; USACE 1995a; Busby et al. 1996).

Summer steelhead trout are not native to the McKenzie River or the Willamette River basin. They were first introduced into the McKenzie system in 1968 (ODFW 1990e).

Bull trout exist as three isolated populations in the McKenzie River subbasin, including a population in the mainstem McKenzie River below Trail Bridge Dam, a population above Trail Bridge Dam, and in the South Fork McKenzie above Cougar Dam (ODFW 1997b). The population of bull trout in the mainstem McKenzie appears to be the largest and most secure in the Willamette River basin (ODFW 1997b). Fish from this population spawn in Anderson Creek, and they have been observed to overwinter in pools in the McKenzie River from above McKenzie Bridge to below Leaburg Dam. An adult was also collected by ODFW in spring 1999 at the confluence of the McKenzie and Willamette rivers (Unthank 1999). Access to Olallie Creek for spawning adults was improved in 1995. Although Elk Creek could potentially support bull trout, the stream has elevated water temperatures resulting from timber harvest. The population above the Trail Bridge Dam is believed to contain only a handful of adults and recovery is limited by lack of spawning and juvenile rearing habitat (ODFW 1997b), by angling and competitive pressures from naturalized populations of brook trout (Unthank 1999). The population of bull trout in the South Fork McKenzie is limited by Cougar Dam, which is a migration barrier. The number of adult bull trout above Cougar Dam is small, and is estimated at 25 to 75 adults. This population is severely limited by the lack of spawning habitat (ODFW 1997b), which occurs primarily in the Roaring River according to redd counts (Unthank 1999). Other pressures on the population above Cougar Dam include incidental mortality from catch and release.

Oregon chub are not currently known to exist in the McKenzie River subbasin (Scheerer et al. 1998).

Historically, the McKenzie River was famous for it large rainbow trout, known locally as “redsides.” It also produced cutthroat trout, whitefish, chub, dace, suckers, sculpins, lamprey, northern pikeminnows, redside shiners, and chiselmouth (USACE 1982; McIntosh et al. 1995). Warmwater species are generally restricted to below the Mohawk River, and dace, sculpin and suckers are the only nongame fish found regularly above the mouth of the Blue River (USACE 1982).

5.4 MIDDLE FORK WILLAMETTE RIVER

The Middle Fork Willamette River originates in the Cascade Mountains and flows northwesterly for nearly 84 miles before joining the Coast Fork Willamette River (near the city of Eugene) to form the Willamette River, approximately 188 miles upstream of the confluence with the Columbia River. Fall Creek, a tributary to the Middle Fork Willamette River is also part of the subbasin. Major tributaries with fish production potential are listed in Table 5-9. Most of the subbasin is characterized by steep ridges, narrow valleys, and volcanic soils typical of the west slope of the Cascades. Relatively recent lava deposits near the headwaters contain many large springs (McIntosh et al. 1995). The Middle Fork Willamette River originates in two connecting lakes formed by lava flows, Opal and Timanogas lakes. The subbasin is mostly forested, although fire and commercial logging have created a mosaic of different aged, but relatively young stands of trees (ODFW 1990f). Below about 5,500 feet MSL, the tributaries have incised steep, narrow valleys through the moderate to highly resistant undifferentiated tuffs, basalts and andesites of the older Western Cascades formations (Walker and MacLeod 1991). Numerous ancient deep-seated landslides have been mapped in these geologic units, and many valleys above 2,200 feet MSL contain easily eroded glacial deposits, morainal material or occasional deposits from pyroclastic flows and lahars. The narrow valley inundated by Lookout Point Reservoir probably formerly contained discontinuous alluvial deposits comparable to those currently mapped between Lookout Point Reservoir and Hills Creek Dam (Walker and MacLeod 1991). Older, resistant Miocene and Oligocene basaltic lava flows are exposed in the canyon walls. Downstream of Dexter Dam, the valley begins to widen rapidly, with the Middle Fork Willamette River following the eastern margin until it joins the Coast Fork Willamette River near Springfield, Oregon. Near the mouth, the Middle Fork Willamette River forms a floodplain on a valley floor bordered by steep foothills (ODFW 1990f).

The profile of the Middle Fork Willamette River generally reflects the transition from resistant volcanic parent material through the more easily erodible tuffaceous sedimentary rock, to uncohesive alluvial sediments. The channel slope decreases from 2.6 percent upstream of Hills Creek Reservoir to approximately 0.5 percent between Hills Creek Dam and Lookout Point Reservoir. Downstream of Lookout Point Dam the channel slope is less than 0.2 percent. Stream gradients range from an average of 7 percent in higher elevation tributaries to 1 percent in the mainstem (ODFW 1990f). Surveys conducted in 1937 and 1938 noted that although numerous tributaries empty into the river, the mouths are relatively steep and therefore, inaccessible to anadromous fish (McIntosh et al. 1995). Accessibility is also a concern for the tributaries downstream of Dexter Dam (ODFW 1990f).

Table 5-9. Major streams of the Middle Fork Willamette River subbasin with fish production potential (data compiled from Mattson 1948; Willis et al. 1960; Hutchison et al. 1966a; Fulton 1968; Fulton 1970; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present Listed [1] Fish Species
Downstream of Dexter Dam		
MF Willamette River	18	OC, SCh, WSt, BT
Lost Creek	17	SCh, WSt
Downstream of Fall Creek Dam		
Fall Creek	7	OC, SCh, WSt
Little Fall Creek	18	SCh, WSt
Upstream of Fall Creek Dam		
Fall Creek	27	SCh, WSt
Winberry Creek	8	SCh, WSt
Between Dexter Dam and Hills Creek Dam		
NF of MF Willamette	46	OC, SCh, BT
Salmon Creek	24	SCh?, BT
Salt Creek	24	SCh, BT
Upstream of Hills Creek Dam		
MF Willamette River		BT
Hills Creek	15	SCh, BT
Staley Creek	14	SCh, BT
Swift Creek	9	BT

OC = Oregon chub • SCh = Spring chinook • WSt = Winter steelhead • BT = Bull trout

[1] Listed under the Endangered Species Act.

Soils in the subbasin tend to be unstable and fine textured with a high clay content. Mass wasting from steep slopes, plus less severe but more pervasive surface erosion contribute substantial sediment and turbidity to downstream areas (ODFW 1990ef). Shoreline erosion from winter wave action and resultant high turbidity is substantial in Hill Creek Reservoir and in downstream waters (ODFW 1990f).

Although the majority of the streams draining to the four USACE reservoirs are located within the Willamette National Forest, Dexter and Fall Creek reservoirs are both situated outside forest boundaries. The North Fork of the Middle Fork Willamette River is a designated National Wild and Scenic River. Commercial forestry, the leading land-use in the subbasin, has contributed to degradation of fish habitat by increasing sediment inputs and water temperatures (ODFW 1990f). Mature and old-growth forest currently occupy approximately 36 percent of the Hills Creek Reservoir drainage, which has been estimated to constitute a loss of 55 percent from historic conditions (Unthank 1998). There is limited mining activity in the Middle Fork Willamette River subbasin (Unthank 1998).

5.4.1 Hydrology

The Middle Fork Willamette River drains an area of approximately 1,360 square miles. Streamflow in the Middle Fork Willamette River subbasin reflects the same general seasonal distribution as other Willamette River basin tributaries, with the majority of runoff occurring during the winter and low flows during July and August. The Middle Fork Willamette River hydrograph typically exhibits a smaller, secondary peak in May and June because headwater elevations are high enough to develop a seasonal snowpack and melt. Flows in the Middle Fork Willamette River have been controlled by the Lookout Point-Dexter Project, Hills Creek Dam, and Fall Creek Dam since 1954, 1961, and 1965, respectively.

Flood control operations at the dams have substantially decreased the magnitude and frequency of extreme high flow events in the lower river. Flows greater than 20,000 cfs were common in the Middle Fork Willamette River above Salt Creek prior to construction of Hills Creek Dam. Since construction of the project, the two-year recurrence interval flood has decreased from about 11,800 cfs to about 5,200 cfs and no flows greater than about 10,000 cfs have occurred (See Appendix F). A similar reduction was observed in Fall Creek, where the two-year return interval flood declined from about 10,000 cfs to about 3,800 cfs (See Appendix F). Although the pre-dam flow record below Dexter Dam is not long enough to conduct such a comparison, the overall magnitude of the flow reduction there is expected to have been greater than that observed above Salt Creek because of the size of Lookout Point Reservoir and the influence of Hills Creek Reservoir.

Flows are naturally lowest in the early fall. The average daily flow at Dexter in September prior to dam construction was 846 cfs. Since construction of the projects, the average daily flow in September has increased to 2,760 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically because storage is available to redistribute flood volumes and release water later in the year for flow augmentation purposes.

5.4.2 Sediment Transport

Lookout Point Dam has blocked the downstream transport of sediment from approximately 1,000 square miles of the Middle Fork Willamette River subbasin. Fall Creek Dam, completed in 1966, traps sediment from an additional 184 square miles. Together, these projects have reduced the area contributing sediment to the lower Middle Fork Willamette River by over 85 percent. The only remaining tributaries that contribute sediment are Little Fall Creek, a tributary to Fall Creek below the dam, and several small streams including Rattlesnake Creek, Hills Creek, and Wallace Creek. All of these tributaries must flow across low gradient fans or the alluvial valley formed by the Middle Fork Willamette River, where gravel and cobble sized sediment are most likely deposited before they can be transported into the mainstem.

There is little information available on the effects of dam closure on the Middle Fork Willamette River. Bedload from upstream reaches is trapped behind each dam. Prior to dam construction, the lower Middle Fork Willamette was described as having large areas of gravel bars and riffles with gravel and cobble substrates (Willis et al. 1960). Above Hills Creek Reservoir, the channel changed in several locations from a narrow, single thread to a wider, braided form in response to landsliding that occurred during the December 1964 storm. Landslides are the dominant erosional process in the upper basin and can supply the channel with large amounts of sediment (Lyons and Beschta 1983). Peak flows downstream of Dexter Dam have been reduced to less than the pre-dam two-year return interval event. The substantial reduction in sediment supply below Dexter Dam most likely offset the reduced sediment transport capacity, resulting in a coarsening of the bed and degradation of the low gradient reach between the dam and the Willamette River (Table 5-3). Assuming that development of an armor layer has occurred and has extended downstream at a rate of 2,000 feet per year (Perkins 1999), the entire reach below Dexter Dam would have become armored by 1999. A recent survey by the ODFW notes that accessibility to salmonids is a concern on the tributaries downstream of Dexter Dam (ODFW 1990f). This could indirectly indicate that the mainstem has degraded in response to dam construction.

5.4.3 Bank Protection and Channelization

In 1947, the USACE noted that approximately six miles of levees with a mean height of six feet would be required to provide adequate channel capacity for controlled flood discharges released from the Middle Fork Willamette River dams (USACE 1947). As of 1989, approximately 50 percent of the lower eight miles of channel had been protected by levees or revetments (USACE

1989d). This has reduced fish habitat complexity and has likely increased the sediment transport capacity of the river, resulting in channel incision.

5.4.4 Floodplain maintenance and side channel connectivity

Absent specific studies, it is likely that reduction in flood flows, sediment supply and large woody debris, and construction of extensive levees and revetments, have all contributed to a reduction in habitat complexity and floodplain function in the alluvial channel downstream of Dexter Dam, as has been observed elsewhere in the Willamette system (EA 1991a; Minear 1994; Benner and Sedell 1997). However, the extent to which this has occurred is presently unknown. Channel incision as a result of the reduced sediment supply is expected to have been particularly severe in the Middle Fork Willamette River. Channel incision may have led to perching and isolation of off-channel habitats from the mainstem between Dexter Dam and the segment with extensive levees and revetments downstream of RM 8.

5.4.5 Large Woody Debris Transport

Construction of dams on the Middle Fork Willamette River disrupted the transport of LWD, reducing the supply of wood and organic material to downstream reaches. Wood and organic material trapped behind the Hills Creek, Lookout Point, Dexter and Fall Creek dams would have eventually been transported to the lower Middle Fork Willamette River and from there to the Willamette River. The influence of dams disrupting the downstream transport of LWD relative to other land use activities in the basin is unknown. Historically, it was common practice for landowners and river guides to remove LWD for the channel, for flood control and navigation concerns or to sell marketable wood (Minear 1994). These practices, in conjunction with agricultural and urban development of the lands adjacent to the lower river had probably substantially reduced the amount of LWD in the river even prior to construction of the dams. Land uses such as agriculture often result in permanent loss of riparian vegetation, such that contributions of LWD from headwater streams were probably the most important source of LWD and organic matter prior to dam construction.

5.4.6 Fish Habitat

A survey of the Middle Fork Willamette River conducted in the late 1930s noted that most of the suitable salmonid spawning area was located above Lookout Point, which is near the upstream end of Lookout Point Reservoir, extending upstream to the survey boundary near Echo Creek (McIntosh et al. 1995). Although the lower 35 miles of the river contained "excellent appearing" spawning habitat, it was used rarely and spring chinook salmon preferred to spawn further upstream (Parkhurst et al. 1950). Riffles and rapids were interspersed with large pools up to 400 yards long, and abundant small pools were provided by boulders. Banks were generally high or well vegetated, effecting abundant shading of the stream (McIntosh et al. 1995). The 8.3-mile section below Dexter Dam was characterized in 1979 as containing large cottonwood trees growing at the edge of the banks with little overhanging vegetation, long areas of slow water, few deep pools, and broad riffles. The section below Hills Creek Reservoir was characterized by overhanging willow and alder bordered by large cottonwood trees, numerous deep pools, and long riffle areas (Ely 1981).

Jones and Gresswell (1996) characterized current conditions of the quantity and quality of spawning and rearing habitat for spring chinook salmon in tributaries above the four USACE dams found in the Middle Fork Willamette River system, and compared them with conditions observed in the 1930s. They concluded that there is still abundant spawning and egg incubation habitat for spring chinook, as well as fall and winter juvenile rearing habitat. The number of deep pools in the Middle Fork Willamette River providing holding habitat for adult salmon prior to spawning was noted to have declined, whereas the amount and quality of gravel available for spawning and incubation remained relatively similar (Jones and Gresswell 1996). Habitat for fry colonization and summer rearing was thought to be potentially limiting in the mainstem river, primarily due to the low abundance of secondary channels and LWD compared to undisturbed systems. Estimates of available habitat and potential smolt production are presented by tributary in Table 5-10. According to Thompson et al. (1966), the North Fork produced more spring chinook salmon than any other Middle Fork tributary

Water temperatures in the Middle Fork Willamette River below Dexter Dam are too warm (> 11°C) during September and early October and result in premature incubation and early rearing of spring chinook (ODFW 1990f). Summer water temperatures are also quite high (15°C) and can limit salmonid production in the mainstem (ODFW 1990f) and in tributaries below Lookout Point Dam (Hutchison et al. 1966b). Fifteen reaches within the Middle Fork Willamette River subbasin are identified by ODEQ (1998) on their 303(d) list as being water quality impaired because of high summertime water temperatures. Spawning below Dexter Dam has been delayed and survival of incubating embryos is poor due to warm water temperatures (USACE 1997).

Table 5-10. Spring chinook smolt production potential in the Middle Fork Willamette River subbasin (based on an assumed juvenile density of 0.2 fish/m^2 of habitat).

Tributary	Habitat (m^2)*	Number of Smolts
Above Lookout Point to Hills Creek		
Black Creek	45,400	9,088
Black Creek (1995)	10,200	2,034
Christy Creek	61,400	12,274
Eagle Creek	10,400	2,087
Fisher Creek	12,200	2,437
North Fork of Middle Fork Willamette River	240,000	48,052
Salmon Creek	198,000	39,612
Salt Creek	135,000	26,954
	Total Production	142,538
Above Hills Creek		
Coal Creek	19,900	3,976
Middle Fork Willamette River	393,000	78,595
Noisy Creek	6,460	1,292
Simpson Creek	5,390	1,077
Staley Creek	35,000	7,001
Swift Creek	14,300	2,859
	Total Production	94,800

Source: Jones and Gresswell 1996 as reported in USACE 1997.

* Interpolated from Jones and Gresswell 1996 estimates as reported in USACE 1997.

Skeesick and Jones (1988) reported that an estimated 77.1 miles of streams in the Willamette National Forest that drain to the Middle Fork Willamette River lacked adequate shade in 1981 as a result of adjacent clearcuts. Of this total, 22.3 miles were identified in the North Fork of the Middle Fork Willamette River drainage; 17.6 miles were identified in the Salmon Creek drainage; 30.2 miles were located in the Middle Fork of the Willamette River; and 7.0 miles were within the Hills Creek drainage. The Salmon Creek drainage has experienced particularly significant habitat degradation due to erosion, debris accumulation, and loss of shade (Skeesick and Jones 1988). Summer water temperatures on tributary streams are currently elevated over historic conditions because of riparian harvest, but are still relatively cool: the 7-day maximum temperature is generally below 10.0°C (Unthank 1998).

5.4.7 Fish Distribution

A hatchery rack maintained by the state of Oregon was located historically below the city of Oakridge and posed a major obstruction to fish passage. The rack prevented nearly all spring chinook from accessing habitat in the Middle Fork Willamette River system upstream of this location. The location of the rack was later moved above Oakridge to a site near the mouth of Salmon Creek, where the rack diverted all returning adults into the Salmon Creek Hatchery. The rack was occasionally washed out by high flows, which periodically allowed fish to escape to natural spawning grounds (Thompson et al. 1966; McIntosh et al. 1995). Until 1921, hatchery policy was to transfer most or all of the eggs away from the spawning streams and into other river systems (Cone and Ridlington 1996).

Another major obstruction to fish passage was located in the North Fork of the Middle Fork Willamette River, where an inefficient fish ladder associated with the Westfir Lumber Mill Dam blocked migration approximately 1.3 miles above the mouth, denying access to a substantial amount of spawning habitat (Thompson et al. 1966; McIntosh et al. 1995). By 1990, the Westfir lumber operation was defunct, but the dam remained a complete barrier to upstream migration until it was finally breached by ODFW in 1995.

Spring chinook salmon were abundant historically in the Middle Fork Willamette River subbasin, and were the second most abundant chinook stock above Willamette Falls (next to the McKenzie River) in the period shortly before dam construction (Mattson 1948; ODFW 1990f). Mattson (1948) estimated that 98 percent of the 1947 spring chinook run in the Middle Fork Willamette River system spawned upstream of the Lookout Point (aka "Meridian") Dam location, and that the remaining 2 percent spawned upstream of the Fall Creek Dam site. The North Fork, Fall Creek, Salt Creek, and Salmon Creek have been noted to be the principal spawning tributaries for spring chinook salmon (Mattson 1948; ODFW 1990f). Hutchison et al. (1966b) commented that the North Fork of the Middle Fork Willamette River contained possibly the finest spring chinook salmon habitat in Oregon. The present distribution is limited to only 20 percent of the historical area due to the construction of the USACE dams (ODFW 1990f). Spawning of spring chinook has now shifted to the area below Lookout Point, an area that was not used for spawning prior to the construction of the dams. Only ten redds were observed in the mainstem Middle Fork Willamette River in 1998, all above Jasper (Lindsay et al. 1999). Hatchery chinook have been released in the Middle Fork Willamette River basin since 1919 (USACE 1997). Chinook salmon migrating from previous releases have residualized in Hills Creek Reservoir (J. Ziller, ODFW, personal communication, August 1999).

Winter steelhead trout were, at most, limited in historical distribution and abundance (ODFW 1997b; ODFW 1990f), and there is no evidence that they were present in 1911 (Fulton 1970). Fish from the North Santiam River stock were introduced in 1956, and although they are believed to have become established in Fall Creek, Little Fall Creek, Lost Creek, and the Middle Fork Willamette River below Dexter Dam, their populations have not been monitored extensively (ODFW 1997b). In the years 1992 through 1996, less than ten adult fish have returned to Fall Creek Dam (ODFW 1997b). There may have been 100 to 200 adults returning to the Middle Fork Willamette River during the same period (ODFW 1997b). Winter steelhead presently spawn below Dexter and Fall Creek dams and in several of the larger tributaries, including Wallace, Rattlesnake, Sturdy, Portland, North Fall, and the North Fork and South Fork of Winberry creeks (ODFW 1990f).

Fall chinook, coho, and sockeye salmon were stocked historically in the lower Middle Fork Willamette River beginning in 1953 (Hutchison et al. 1966b; USACE 1982). This practice is no longer continued.

Bull trout were reported to have been distributed historically in the Middle Fork Willamette River and North Fork of the Middle Fork Willamette River, Salt Creek, Swift Creek, Staley Creek, and presently in Hills Creek Reservoir (Hutchison et al. 1966b; ODFW 1997b). The population became isolated above Hills Creek Dam and the last confirmed sighting of a bull trout in this system was a photograph taken by an angler in 1990 (ODFW 1997b). Extensive snorkel and electroshocking surveys were conducted from 1993 through 1997 by USFS and ODFW personnel, but failed to find any bull trout (Unthank 1998). Introductions of fry from Anderson Creek in the McKenzie River occurred in both 1997 and 1998. It is unknown if juvenile bull trout 5-7 cm in length observed during recent surveys near the Packard campground in the Hills Creek Reservoir were from those introductions (Seims 1997).

Oregon chub populations are presently greatest in number in the Middle Fork Willamette River subbasin (Scheerer et al. 1998). In 1937, surveys reported observing large schools of cyprinid fry (which probably included Oregon chub) in quiet backwaters of the river. Recent observations indicate there are only 13 populations of Oregon chub in the Middle Fork Willamette River basin (Scheerer et al.1998).

In addition to anadromous fish, the Middle Fork Willamette River historically supported populations of chubs, suckers, sculpin, dace, and whitefish. In addition, rainbow and cutthroat trout were present in fair numbers (McIntosh et al. 1995; USACE 1997). Construction and operation of Dexter and Lookout Point dams blocked access to at least 80 percent of anadromous fish spawning habitat in the Middle Fork Willamette River subbasin (USACE 1997). Largescale suckers, northern pikeminnow, redside shiners, and chiselmouth are presently common in the Middle Fork Willamette River reservoirs and their headwaters (USACE 1982).

5.5 COAST FORK WILLAMETTE RIVER

The Coast Fork Willamette River drains the Calapooya Mountains, and is approximately 40 miles long and drains an area of 665 square miles. The river joins the Middle Fork Willamette River just south of the city of Eugene to form the Willamette River. There are relatively few streams in the subbasin known to have supported listed fish species (Table 5-11). Ninety percent of the Coast Fork Willamette River subbasin is mountainous, with a narrow floodplain that covers only about 40 square miles in the lowest reaches of the basin. Lower Mosby Creek, and the Row and Coast Fork Willamette rivers downstream of the dams, flow through valleys approximately one-half to one mile wide that are filled with erodible alluvial sediments. Much of the area has been developed for agriculture. The valley widens considerably downstream of the confluence of these three streams. Bedrock in the western portion of the basin, including the majority of the Coast Fork Willamette River and Mosby Creek drainages is composed of marine sand and siltstones of the Eugene formation (Walker and MacLeod 1991). Slopes are gentle relative to the volcanic parent materials to the east. The marine sand and siltstones weather relatively quickly to silt and sand sized sediment. The Row River drains nearly 60 percent of the basin and flows through a complex mixture of sedimentary and volcaniclastic rocks, including tuffs, mudflow and lahar deposits and basalt flows dating to the Miocene and Oligocene. Mineral bearing intrusive dikes are common in the headwaters of the Row River, and the area continues to be mined both commercially and recreationally (Weyerhaeuser 1999; USFS 1999). Bedrock tends to be more resistant than the marine sand and siltstones.

Stream gradients are generally high in the upper subbasin and gentler in the middle to lower reaches (ODFW 1990d). The longitudinal profile of the Coast Fork Willamette River reflects the difference in parent material between the more resistant volcanic materials underlying the Row River, and the more erodible marine silt and sandstones of the Coast Fork Willamette River and Mosby Creek basins (see Figure 1, ODFW 1990d). Downstream of the confluence of the three major tributaries, the gradient is less than 0.2 percent. The Row River downstream of Dorena Dam also has an average slope of about 0.2 percent, but quickly increases from 0.5 percent to more than 2 percent within 30 miles upstream of the dam. The Coast Fork Willamette River upstream of Cottage Grove Dam continues at a slope of approximately 0.3 percent before rapidly steepening upstream of RM 50. Slopes in the upper Row River drainage are steep, and the streams flow through narrow, deeply incised valleys.

Table 5-11. Major streams of the Coast Fork Willamette River subbasin with fish production potential (data compiled from USFWS 1948; Willis et al. 1960; Hutchison et al. 1966a; Fulton 1968; Fulton 1970; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present Listed[1] Fish Species
Downstream of Cottage Grove Dam		
Coast Fork Willamette River	31	OC, SCh, WSt?
Upstream of Cottage Grove Dam		
Coast Fork Willamette River	24	OC?, SCh
Downstream of Dorena Dam		
Row River	9	SCh, WSt?
Mosby Creek	16	SCh?, WSt?
Upstream of Dorena Dam		
Row River	13	SCh?
Sharps Creek	16	SCh?

OC = Oregon chub • SCh = Spring chinook
[1] Listed under the Federal Endangered Species Act.

The lower area of the Coast Fork Willamette River subbasin is heavily farmed, whereas the upper basin is primarily forested and much is used for timber production. The subbasin has also experienced extensive mining of metals in the upper watershed, and of sand and gravel in the lower basin. Mercury has been mined intensively in the Black Butte area, located in the upper reaches of the mainstem Coast Fork Willamette River, and the Bohemia Mining District in the upper Row River drainage. The latter has been the most productive mining district in the Oregon Cascade Range for gold, silver, copper, lead, zinc, and antimony (ODFW 1990d).

Mercury has been found in fish from Cottage Grove and Dorena reservoirs at levels potentially hazardous to human consumption (ODEQ 1998). The highest mercury loadings are typically seen in large resident fish that prey on other fish, including bass, northern pikeminnow, and large trout (ODHR 1997). Both lakes have fishing regulations that are aimed at limiting the consumption of these fish. Mercury probably enters Cottage Grove Reservoir as a result of mining higher up in the watershed, but the contribution of mining activities to the mercury problem is relatively unknown. Mercury is a naturally-occurring element in much of the Cascade Mountains and in smaller amounts in the Coastal Range; it originates from soils, volcanic rocks, and geothermal water sources (ODHR 1997). Mercury can be found in the environment as free metallic mercury, in a number of chemically combined soil or rock constituents, or in plant and animal tissue where it is mostly in the form of methylmercury. A recent report indicated that a point source, Black Butte Mine, resulted in mercury concentrations in Cottage Grove Reservoir that are higher than would result from natural (background) sources, atmospheric deposition, and use of the metal during processing of gold (Park and Curtis 1997).

Juvenile spring chinook were reared in Cottage Grove Reservoir by ODFW during 1969 through 1976, but the resulting smolts were believed to have low survival upon entering salt water as a result of accumulated mercury (ODFW 1990d). High mercury levels have also been found in several fish species collected throughout the length of the mainstem Coast Fork Willamette River; this reach is also listed by ODEQ as impaired due to mercury (ODEQ 1998).

High turbidity and sediment problems have been noted to impact fish production in the basin. The problems result from shoreline erosion caused by winter-time wave action and sediment loading from storms and forestry (ODFW 1990d). Additionally, the banks of the mainstem river have been extensively modified for over two miles in the vicinity of the town of Cottage Grove. Lumber mills have also contributed to water pollution to the basin (ODFW 1990d).

Both Cottage Grove and Dorena reservoirs have shallow shorelines that allow the development of extensive vegetated shoal areas (Seim 1997). This shoal area increases the diversity of insect populations that provide important prey items for warm water fishes (Seim 1997).

5.5.1 Hydrology

The Coast Fork Willamette River drains an area of approximately 642 square miles. Streamflow in the Coast Fork Willamette River subbasin reflects the same general seasonal distribution as other Willamette River tributaries, with the majority of runoff occurring during the winter, and low flows during July and August. The headwater elevations are lower than in the Middle Fork Willamette River subbasin and the Coast Fork Willamette River hydrograph does not exhibit a spring snowmelt runoff.

Flows in the lower Coast Fork Willamette River have been controlled by Dorena and Cottage Grove dams since the early 1940s. Flood control operations at the dams have substantially decreased the magnitude and frequency of extreme high flow events in the Coast Fork Willamette and Row rivers. Flows greater than 15,000 cfs were common in the Row River near Cottage Grove prior to construction of Dorena Dam. Since construction, the two-year recurrence interval event has decreased from about 11,100 cfs to about 4,900 cfs, but flows up to 15,000 cfs have occurred on rare occasions (see Appendix D). Although the pre-dam flow record below

Cottage Grove Dam is not long enough to conduct such a comparison, the degree of flood flow reduction there is expected to have been similar to that observed on the Row River.

Flows are lowest in the late summer and early fall. The average daily flow of the Coast Fork Willamette River near Goshen in August was 95 cfs prior to dam construction. Since construction, the average daily flow in August has increased to 481 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically, because storage is available to redistribute flood volumes and release water later in the year for flow augmentation purposes.

5.5.2 Sediment Transport

Dorena and Cottage Grove dams have blocked downstream transport of sediment from approximately 54 percent of the 680 square mile Coast Fork Willamette River subbasin. Mosby Creek remains undammed and is the only major tributary that currently contributes sediment to the lower Coast Fork Willamette River.

There is little existing information on the effects of dam closure on the Coast Fork Willamette River and the Row River. Bedload from upstream reaches is trapped behind Dorena and Cottage Grove dams. Maximum flows in the Row River near Cottage Grove have decreased, but flows greater than the pre-dam two-year return interval still occur albeit on an infrequent basis. Because flows from approximately 46 percent of the basin (including Mosby Creek) are unregulated, the reduction in flood flows in the lower Coast Fork Willamette River is not expected to be as great as in other regulated subbasins. The most likely response below the Row River has probably been a loss of some in-channel gravel storage, coarsening of the bed, and encroachment of riparian vegetation (Table 5-3).

The effects of flow regulation and reduced sediment supply have probably been greatest on the Coast Fork Willamette River upstream of the confluence with the Row River, and on the Row River upstream of the confluence with Mosby Creek. There are no major tributaries that contribute flow or sediment to either of these segments. Assuming that these segments experienced moderate to high reductions in peak flows and large reductions in sediment supply, the most likely response would have been a loss of smaller gravels, armoring, and encroachment of riparian vegetation (Table 5-3). If development of an armor layer has occurred, and has extended downstream at a rate of 2,000 feet per year (Perkins 1999), the nine mile reach below Cottage Grove Dam would have become armored by about 1966. A four-mile stretch of the Row River between Dorena Dam and the confluence with Mosby Creek would have experienced similar changes between 1949 and 1960. Prior to construction of the dams, substrates in the

Coast Fork Willamette River mainstem in 1938 were reported to be almost equal parts of large, medium, and small gravel; the Row River had relatively larger rock substrate than the Coast Fork Willamette River (McIntosh et al. 1995). Present conditions and sizes of substrates in these systems are not well documented, but may reflect some armoring of the streambed (Section 5.5.6).

5.5.3 Bank Protection and Channelization

The USACE indicated in 1947 that construction of eleven-foot high levees along the Coast Fork Willamette River from Cottage Grove (RM 23) to the confluence with the Middle Fork Willamette River would prevent flood damage, but determined that the cost of constructing such levees outweighed the benefits at that time (USACE 1947). A need for approximately 4.3 miles of levee along the Row River was also noted. As of 1989, approximately 5 miles of levees and revetments had been constructed on the Coast Fork Willamette River downstream of RM 12 (USACE 1989d). An additional one mile of levees and revetments hardened banks on the lower Row River (USACE 1989d). Construction of these levees and revetments created probably had a greater impact on channel morphology of the lower Coast Fork Willamette River than the reduced flows and sediment supply resulting from Dorena and Cottage Grove dams. The most likely effects were a simplified channel form, a reduction in mid-channel bars and islands (if present), and a coarsening of the bed.

5.5.4 Floodplain Maintenance and Side Channel Connectivity

Absent specific studies, it is likely that reduction in flood flows, sediment supply and LWD, and construction of extensive levees and revetments, have all probably contributed to a reduction in habitat complexity and floodplain function in the alluvial channel downstream of Cottage Grove and Dorena dams, as has been observed elsewhere in the Willamette River system (EA 1991a; Minear 1994; Benner and Sedell 1997). The extent to which this has occurred is presently unknown. Channel incision, as a result of the reduced sediment supply is not expected to have been particularly severe since sediment supply and flows from almost 50 percent of the watershed are still contributed to the mainstem Coast Fork Willamette River. However, an overall coarsening of the bed, loss of complexity, and narrowing of the channel could be expected.

5.5.5 Large Woody Debris Transport

Construction of dams on the Coast Fork Willamette River and Row River also disrupted the transport of LWD, reducing the supply of wood and organic material to downstream reaches. Wood and organic material trapped behind the dams would have eventually been transported to the lower Coast Fork Willamette River and from there to the Willamette River. The influence of dams disrupting the downstream transport of LWD relative to other land use activities in the basin is unknown. Historically, it was common practice for land owners and river guides to remove LWD for the channel, for flood control and navigation concerns or to sell marketable wood (Minear 1994). These practices, in conjunction with agricultural and urban development of the lands adjacent to the lower river probably substantially reduced the amount of LWD in the river prior to the construction of dams. Land uses such as agriculture often result in permanent loss of riparian vegetation, such that contributions of LWD from headwater streams were probably the most important source of LWD and organic matter prior to dam construction.

5.5.6 Fish Habitat

Substrates in the Coast Fork Willamette River mainstem were reported to be almost equal parts of large, medium, and small gravel in the late 1930s. The available spawning area, based on substrate and flow, averaged approximately 15 percent of the total area of the mainstem. Extensive pools and slow deep riffles in the lower section of the Coast Fork Willamette River, and cascades and fast riffles in the upper section, made much of the medium and small cobble substrates unsuitable for spawning (McIntosh et al. 1995). Hutchison et al. (1966b) reported the results of spawning gravel surveys conducted throughout the Coast Fork Willamette River subbasin. Although spawning gravel was noted to be scarce in many streams, it was thought to limit salmonid production in only a few of the smaller tributaries. Three sections of the Coast Fork Willamette River were also assessed in 1979 for habitat conditions (Ely 1981). The river was noted to flow through a variety of habitat for salmonids ranging from good to poor (near the sewage plant), and through an area of slack water conducive to warmwater fish production. The middle section, from the sewage plant to the Row River, had poor water quality and few game fish. Below the confluence with the Row River, water quality improved and more gamefish were present (Ely 1981).

Surveys of the Row River in the late 1930s observed relatively larger rock substrates than in the Coast Fork Willamette River. Available spawning area was estimated to be less than 10 percent. A 25-foot high falls (Wildwood Falls) located approximately 18 miles upstream from the mouth of the river marked the limit of upstream fish migration. The stream was not noted to support a large fish population, because of the large amount of bedrock bottom present (McIntosh et al. 1995). The gradient downstream of the dam site is relatively low and is higher in the upper section upstream of the dam site.

Water temperatures above Dorena Reservoir on the Row River and Cottage Grove Reservoir on the Coast Fork Willamette River are generally favorable for salmonid production and rarely exceed 21.1°C (ODFW 1990d). However, elevated water temperatures within and below the reservoirs favor the production of warmwater and nongame fishes (ODFW 1990d). Six reaches in the basin, including the mainstems below each dam, are included on the state 303(d) list as being water quality impaired due to elevated summer-time water temperatures (ODEQ 1998). The Coast Fork Willamette River is also listed as having its water quality impaired year-round from the mouth to the dam because of elevated fecal coliform bacteria (ODEQ 1998).

5.5.7 Fish Distribution

Spring chinook salmon were last seen in the Coast Fork Willamette River subbasin roughly 20 to 30 years prior to a 1938 survey (McIntosh et al. 1995). The lack of an anadromous salmonid population during the survey was believed to have resulted from anthropogenic passage obstructions and water pollution (McIntosh et al. 1995). Thompson et al. (1966) reported that small runs were seen sporadically “in recent years.” Spring chinook salmon were noted to have spawned historically in the Row River and possibly in Mosby Creek, but flash dams from logging operations had exterminated this run (USFWS 1948). Construction of Cottage Grove and Dorena dams eliminated access to about 80 miles of potential anadromous stream habitat, although populations of spring chinook and winter steelhead were possibly never abundant historically in the system (ODFW 1990d). Hatchery-produced spring chinook were released into the Coast Fork Willamette River subbasin in the early 1950s, and during 1968 through 1975. The releases never resulted in a self-supporting population and any spring chinook that enter the system are presumed to be strays (ODFW 1990d).

Winter steelhead were released from hatchery production into the Coast Fork Willamette River subbasin from 1950 through 1960 and small sporadic runs of winter steelhead in the Coast Fork Willamette River were reported during that period (Thompson et al. 1966). The run is currently considered to be minimal (less than 100 adults) to nonexistent. The basin may occasionally attract adult strays or hold rearing juveniles originating from the nearby Middle Fork Willamette River subbasin (ODFW 1990d).

Oregon chub were present historically in the Coast Fork Willamette River. A single isolated population of Oregon chub occurs presently in Camas Swale, a small tributary that enters the river at approximately RM 10 (USFWS 1998a).

Resident rainbow and cutthroat trout are abundant in the upper subbasin where conditions are suitable. They also occur in the reservoirs and locations downstream, but are less abundant due to higher water temperatures and predation by warmwater species. Other species noted present in the subbasin include cyprinids (chub and minnows), which made up the bulk of the fish population, and brook trout, whitefish, sculpin, and suckers (McIntosh et al. 1995). Substantial populations of warmwater fish species occur in the reservoirs and in downstream reaches, including largescale suckers, northern pikeminnows, redside shiners, and smallmouth bass (USACE 1982). The dominant species present in the reservoirs are bluegill, sunfish, black crappie, brown bullhead, and largemouth bass (Seim 1997).

5.6 LONG TOM RIVER

The Long Tom River originates on the east slopes of the Coast Range and is approximately 55 miles long. It enters the Willamette River approximately 25 miles downstream of the confluence with the McKenzie River. Neither the mainstem nor tributaries have been noted to contain anadromous fish (Table 5-12). The lower 15 miles of the river flows through flat agricultural lands and old fluvial deposits of the Willamette Valley. Most of the river length courses through alluvium.

Table 5-12. Major streams of the Long Tom River subbasin with fish production potential (data compiled from Mattson 1948; Willis et al. 1960; Fulton 1968; Fulton 1970; McIntosh et al. 1995; Buchanan et al. 1997; USFWS 1998a).

Streams	Minimum Estimate of Stream Miles with Potential Fish Habitat	Past and Present Listed[1] Fish Species
Downstream of Fern Ridge Dam		
Long Tom River	24	OC
Amazon Creek		unknown
Upstream of Fern Ridge Dam		
Coyote Creek	25	unknown
Noti Creek	8	unknown

OC = Oregon chub

[1] Listed under the Federal Endangered Species Act.

The Long Tom River valley is generally lower in elevation than the Willamette River floodplain, and prior to construction of upstream flood control dams, flood flows on the Willamette inundated the entire valley (USACE 1947). Bedrock in the upper subbasin is predominantly medium to fine-grained marine sandstones of the Tyee formation (Walker and MacLeod 1991). Upstream of Fern Ridge Reservoir, there are narrow alluvial deposits mapped in association with the Upper Long Tom River and Coyote Creek, a major tributary to the Long Tom River that enters the reservoir from the south (Walker and MacLeod 1991). The headwaters and tributaries of the upper Long Tom River subbasin are steeper as they flow off the Coast Range. The entire length of the mainstem from its mouth to Fern Ridge Dam has been channelized or otherwise modified by projects related to drainage and irrigation. Fish passage structures were not included during construction of Fern Ridge Dam because anadromous salmonids were considered to be absent from the system (Willis et al. 1960; ODFW 1990d; McIntosh et al. 1995).

More than 90 percent of the subbasin is in private landownership. Agriculture has negatively affected fish production in the Long Tom subbasin as a result of excessive water withdrawals and sedimentation.

5.6.1 Hydrology

The Long Tom River drains an area of 410 square miles. Streamflow in the subbasin reflects the same general seasonal distribution as the mainstem Willamette River, with the majority of runoff occurring from October through March, and low flows during July, August and September. Flows in the Long Tom River have been regulated by Fern Ridge Dam since 1943. A structure was converted in 1951 to divert flows (up to 1250 cfs) from Amazon Creek into Fern Ridge Reservoir, and residual flow in lower Amazon Creek enters the Long Tom River about 6 miles downstream of the dam. There are also several small diversions upstream of Monroe (USGS 1997). The ODFW indicated that "excessive water withdrawals" had negatively impacted fish (ODFW 1990d).

Flood control operations at Fern Ridge Dam have decreased the magnitude and frequency of extreme high flow events, although the overall reduction has been relatively less than has been observed for the other Willamette River projects. The highest flow on record at Monroe, 19,300 cfs, occurred in 1943 after Fern Ridge Dam was constructed. Flows greater than 20,000 cfs have occurred on occasion (see Appendix F).

Flows are naturally lowest in the late summer and early fall. The lowest flow recorded at Monroe prior to construction of Fern Ridge Dam was 7 cfs, and the average daily flows in August and September were 24 cfs and 20 cfs, respectively. Since dam construction, the average daily flows in August and September have increased to 81 cfs 228 cfs respectively (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically because storage is available to redistribute flood volumes and release water later in the year for flow augmentation purposes.

5.6.2 Sediment Transport

Construction of Fern Ridge Dam has blocked the downstream transport of sediment from over 60 percent of the basin since 1941. Major tributaries downstream of the dam include Bear Creek, Ferguson Creek and Schafer Creek. All of these tributaries arise in the foothills of the Coast Range west of the Long Tom River, are unregulated, and thus continue to contribute sediment to the mainstem. However, well-developed alluvial fans at the mouth of each tributary suggest that the majority of gravel to cobble size sediments are deposited before they are transported into the Long Tom River. Most sediment in the mainstem may thus originate presently from streambanks. Historically, the bed between Monroe (RM 6.8) and Fern Ridge Dam (RM 25.7) was estimated to be 90 percent mud and silt, 8 percent bedrock, and 2 percent gravel (Willis et al. 1960). There is little existing information pertinent to the effects of dam closure on the Long Tom River. All bedload from upstream reaches is trapped behind the dam and maximum flows have decreased, although flows that equal or exceed the pre-dam two-year return interval event still occur at a return interval of approximately 7 years. Thus, the expected response of the channel to the dams is degradation in the low gradient reach between the dam and the Willamette River (Table 5-3). Studies of the extent of armoring downstream of dams in sand bed rivers suggest that travel rates for the leading edge of degradation are generally between 0 and 1.2 mile per year, although rates as high as 16 miles per year have been observed (Williams and Wolman 1984). Assuming the effects of degradation travel downstream at the rate of approximately 1 mile per year, degradation resulting from the closure of Fern Ridge Dam would have begun to influence the gage at Monroe by around 1967.

5.6.3 Bank Protection and Channelization

The entire length of the mainstem, from its mouth to Fern Ridge Dam has essentially been channelized, straightened, leveed, or otherwise modified by projects related to drainage and irrigation (ODFW 1990d). Much of the changes were completed before 1947 when the channel had the capacity for a regulated discharge of 3,000 cfs from the reservoir. Further, the stream entered the Willamette River originally near river mile 147, whereas the rectified channel entered near river mile 150 (USACE 1947); presently, the channel is reported to enter at RM 145.9 (Laenen and Risley 1997).

Rip-rap banks influence the amount and type of bank cover in low gradient, silt bottomed channels such as the Long Tom River. Recruitment of sediment and LWD from streambanks has been prevented, further reducing the amount of wood and gravel supplied to the channel; secondary channels or associated wetlands and sloughs have probably been cut off from the mainstem. The channel form has probably thus become simpler. The decreased bank resistance and loss of roughness elements would tend to increase the sediment transport capacity and therefore would likely result in channel incision.

5.6.4 Floodplain Maintenance and Side Channel Connectivity

Prior to construction of Fern Ridge Dam, the lower reach of the Long Tom River was described as sluggish and slough-like with abundant fallen trees and brush (McIntosh et al. 1995). USGS topographic maps depict numerous wetlands and oxbows associated with former Willamette River channel locations in the vicinity of the lower Long Tom River.

While flood flows have not changed substantially in the Long Tom River basin, the reduction in sediment supply and LWD, and construction of levees and revetments have all probably contributed to the reduction in habitat complexity downstream of Fern Ridge Dam. Channel incision resulting from the decreased sediment supply and construction of levees is likely to have occurred, and may have isolated off-channel habitats that were formerly connected to the mainstem. Channel incision and the reduction in the magnitude and frequency of flooding has likely prevented the creation of off-channel habitats (Ligon et al. 1995).

5.6.5 Large Woody Debris Transport

Bank protection structures and agricultural development of lands along the lower river has resulted in the loss of much of the original riparian vegetation, including larger trees. Prevention of downstream transport and loss of streamside forests have probably resulted in an overall decline in the amount of in-channel LWD in the Long Tom River, which used to be abundant (McIntosh et al.1995). Headwater reaches cannot provide LWD because of Fern Ridge Dam. LWD was probably historically important for forming pools and providing overhead cover and velocity refugia for fish during flood flows in the lower Long Tom River, because of the fine bed and bank material present.

5.6.6 Fish Habitat

Habitat conditions were surveyed in the Long Tom River in 1938 around the same time as the construction of Fern Ridge Dam (McIntosh et al. 1995). At that time the streambed was noted to be consistently mud except for the upper ten miles. Gravel suitable for salmonid spawning was not observed. Water quality was turbid and water temperatures were as high as 20.6°C in early June. The lower stretch of river was described as a sluggish slough with abundant fallen trees and riparian vegetation (McIntosh et al. 1995). A subsequent survey of approximately 20 miles of the Long Tom River below Fern Ridge Dam conducted in 1979 found similar stream habitat conditions, but little overhanging vegetation. Salmonids were not observed, and the habitat appeared to be best suited for warmwater fish production (Ely 1981).

Elevated water temperatures and excessive sedimentation within the Long Tom River basin limit production of salmonids. Stream temperatures in the lower subbasin commonly exceed 21.1°C in the summer months, and the mainstem between Fern Ridge Dam and the mouth can exceed 26.7°C (ODFW 1990d). The Long Tom River below Fern Ridge Dam is included on ODEQ's 303(d) list of impaired waterbodies because of elevated temperatures and elevated levels of fecal coliform bacteria (ODEQ 1998).

Substantial decreases in, and modification of, fish habitat have occurred as a result of channelization related to agricultural uses. Livestock waste and other agricultural by-products have caused recurring water quality problems in Coyote Creek and Fern Ridge Reservoir (ODFW 1990d). Coyote Creek is listed as being water quality impaired on ODEQ's 303(d) list because of elevated fecal coliform bacteria levels and low dissolved oxygen concentrations from May through October (ODEQ 1998). Additionally, industrial activities along Amazon Creek have resulted in degraded water quality in the past because of chemical spills (ODFW 1990d), and the stream is currently listed as being water quality impaired because of elevated fecal coliform bacteria levels and low dissolved oxygen concentrations (ODEQ 1998).

5.6.7 Fish Distribution

A 1939 report (U.S. Engineer Office 1939) stated that "the Long Tom River supports no run of game or sport fish. The low summer flow, shallow depths and the occurrence of numerous snags and obstruction in the streams prevent through migration of fish to the headwaters. Local fish life consists primarily of catfish, sunfish and other similar species. Recreational fishing along the stream is practically non-existent." However, the river is now known to support cutthroat trout that most likely move between the Long Tom River and the Willamette River mainstem (ODFW 1990d).

The ODFW considered that the Long Tom River most likely did not support steelhead trout or chinook salmon historically because of naturally poor summer rearing conditions. Juvenile winter steelhead produced in nearby subbasins may rear in the lower Long Tom River presently, when habitat conditions are favorable (ODFW 1990d).

Oregon chub were present historically, but no known populations currently exist in the Long Tom River subbasin (Scheerer et al. 1998).

Fern Ridge Reservoir supports a large warmwater fisheries, including white crappie, bullhead, largemouth bass, bluegill, and pumpkinseed (USACE). During drawdown in later summer, many of these warmwater fish are flushed into the Long Tom River where they are fished for heavily (Daily 1999). The Long Tom River below Fern Ridge Dam also supports populations of suckers, northern pikeminnows, carp, and redside shiners.

5.7 WILDLIFE

5.7.1 Gray Wolf

The last record of a wolf in Oregon was of one killed in 1927 at Sycan Marsh (Ingles 1965), and the species was considered extirpated in the state by 1930. In early 1999, however, a female, radio-collared gray wolf from an experimental population that was introduced into Idaho, entered northeastern Oregon across the Snake River. It was later trapped and returned to Idaho. The gray wolf is still considered extirpated in Oregon.

5.7.2 Columbian White-Tailed Deer

No Columbian white-tailed deer are known to occur in Lane County or other lands in proximity to USACE Willamette Valley projects; the nearest known population is found within 5 miles north of Oakland, approximately 15 miles southwest of Cottage Grove Reservoir, (Peterson, USFWS, personal communication, 2000). The Fern Ridge, Cottage Grove, and Dorena project lands include or are in proximity to grasslands, oak woodland, and riparian forests that would be suitable for the Columbian white-tailed deer, but these suitable habitats are not occupied by this species.

5.7.3 Marbled Murrelet

None of the Willamette Valley Projects include lands designated as critical habitat for the marbled murrelet. Of the Willamette Basin Projects, only Fern Ridge lies within the potential nesting range of the marbled murrelet. At Fern Ridge, a small area (7 acres) of conifer forest that includes Douglas fir is found on Gibson Island on the southeast shore of the lake. While this stand contains large, mature, trees, they lack the structural attributes suitable for nesting by the species.

5.7.4 Aleutian Canada Goose

The Aleutian Canada goose may occasionally be observed away from the Oregon coast. It is possible that individuals of this subspecies may occasionally occur at Fern Ridge. The extensive shallow water habitats of the Fern Ridge Project may provide suitable night roosting habitat during migration. While waterfowl hunting occurs at Fern Ridge, project lands are currently closed to goose hunting. It is not known at this time whether goose hunting would resume on the Fern Ridge, however, all changes to goose hunting in the region is under the direction of the USFWS North American Waterfowl and Wetlands Office.

5.7.5 Bald Eagle

Bald eagles are considered uncommon to locally common throughout in the Willamette Basin during winter; migrants from north of Oregon begin arriving in late October and November (Gilligan 1994). The number of wintering bald eagles varies considerably throughout the winter, often depending upon weather and food availability both locally and elsewhere, but peak numbers occur during January and February. The only known winter roost in the area is in the Coburg Hills north of Eugene, east of Interstate 5. The birds that use this roost are thought to forage on the surrounding upland meadows and sheep pastures, primarily on carrion (afterbirth, stillborn, dead, and other lambs), small mammals, and limited waterfowl. They do not rely heavily upon prey that are dependent upon the Willamette River and its tributaries.

All 13 USACE Willamette Basin projects lie within the Willamette Basin Bald Eagle Recovery Zone, and all are documented to support bald eagles at some time of the year. In 1999, there were 43 documented occupied bald eagle territories in this recovery zone (Isaacs and Anthony 1999). Over half of these nest sites in the Willamette Basin Recovery Zone were on or adjacent to USACE project reservoirs or along the Willamette River. Productivity for territories in the Willamette Basin Recovery Zone in 1999 was 1.08 young per occupied territory (the five-year average was also 1.08). Productivity for Oregon as a whole was 0.97 young per occupied site in 1999, with a five-year average productivity of 0.95.

There are two bald eagle territories on USACE project lands. The Fern Ridge site is at Jean's Peninsula and is considered active. Birds are regularly observed feeding there during the breeding season. The birds at this site successfully reproduced from 1982 through 1985, but a nest tree has not been identified in recent years.

The Eagle Rock territory is on USACE land at the Lookout Point project. The birds from this site frequently forage below Lookout Point dam in Dexter Reservoir, especially in the winter months and in the nest initiation season. They have also been observed flying over Lowell Butte to forage in Fall Creek reservoir, and fishing in the river below Dexter Dam. They may also forage in the western part of Lookout Point reservoir. The eastern boundary of their activities is not known. They are typically not observed around the nest or foraging in Dexter reservoir between the time the young leave in August, through November. They typically return to the nest territory around the first of December. Eagle Rock is a 200-acre sensitive area managed for the protection of bald eagles.

There are three additional nest sites at Lookout Point Reservoir, all on USFS lands. The Lookout Point/Schweitzer Creek pair has been documented at 5 different nest sites. They forage most frequently in the reservoir near their nest site, between School Creek and Hampton. They are seen fishing the river when the lake is lowered, in the vicinity of Armet Creek.

Two new nest sites were located in 1999, one just east of the Lookout Point/Schweitzer Creek pair's nest. A second territory was identified across the reservoir and approximately 1.5 miles south of Ivan Oaks. Eagles have been observed perching on a tall fir near Highway 58 and the west end of the cove in 1998 and 1999, and newly fledged young have been seen on at least one occasion prior to 1998. It is likely that this nest has been established for some time.

Detroit Lake also supports a nesting pair of bald eagles on USFS land adjacent to the lake. The USFS manages activities in and around this nest site. Bald eagle territories are also found on USFS land at Hills Creek and Blue River, on BLM land at Dorena and Green Peter, and on private land at Cottage Grove and Foster.

5.7.6 Northern Spotted Owl

Some coniferous forests in or adjacent to USACE Willamette Basin projects may be suitable nesting habitat for the northern spotted owl. Other habitats may provide foraging or dispersal habitat for the species. Surveys have not been undertaken to determine the potential occurrence of northern spotted owls on USACE project lands. However, several spotted owls have been located near Fall Creek Lake. One nest site has been located within one mile of Cascara Campground, with the home range of the pair including the campground and upper tip of the Fall Creek arm of the lake. Spotted owls do not use the area for nesting however, they forage in the forest on the northern edge of the developed area. Other activity centers occur on adjacent forest lands. At Green Peter Lake, northern spotted owl activity centers are known on adjacent BLM land. Spotted owls are also thought to occur at Lookout Point. Four activity centers are located approximately 0.75 mile or more from the Cougar project, where project lands are under the jurisdiction of the USFS, Willamette National Forest. Additional spotted owl activity centers are probably found at or near the Detroit, Blue River, and Hills Creek projects, also managed by the Willamette National Forest.

5.7.7 Fender's Blue Butterfly

Fender's blue butterfly populations are present at 31 remnant prairie sites in Polk, Yamhill, Benton, and Lane counties. Twenty three of these sites occur on remnants less than 8.3 acres in size, and eighteen of 31 populations consist of less than 50 individuals (including the Fern Ridge sites) (63 FR 3863). Fender's blue butterflies were identified at the Fern Ridge lupine sites in 1990.

Since 1993, annual surveys have been conducted for Fender's blue butterfly in 4 to 7 Fern Ridge management units. Surveys have been conducted by walking transects through meadows containing Kincaid's lupine and counting Fender's blue butterflies every 7 days through the active season. Because silvery blue butterflies (*Glaucopsyche lygdamus*) are present at the same time, the percent of Fender's blue butterflies comprising all blue butterflies seen is estimated by periodic capture. Accurate counts are of low precision due to a variety of factors, are likely to underestimate the actual number of butterflies, and should be considered as an index to population size (Schultz 1994). Beginning in 1997, Paul Severns counted Fender's blue butterflies directly (i.e., without counting silvery blue butterflies or capturing) at several sites on Fern Ridge, and spent more time at the sites than in previous surveys (Severns 1998). This effort resulted in detection of Fender's blue butterflies at two sites where none had been recorded since 1993. Total population estimates at Fern Ridge range from a high of 84 in 1993 to a low of 9 in

1998. The largest population appears to be in the Spires Lane management unit. Other management units that support Fender's blue butterfly include Eaton Lane, Green Oaks, South Green Oaks, and Shore Lane.

5.7.8 Canada Lynx

The South Fork McKenzie River watershed provides suitable foraging habitat for lynx. Specifically, early successional forest cover in the project vicinity may provide winter prey habitat. Denning is not likely to occur at the elevation of any of the Willamette Basin projects. Lynx summer at elevations higher than those found in the project area (i.e., above 5,000 feet).

There have been several detections of Canada lynx in the vicinity of Cougar Lake (Lee, personal communication, 1999). A hair sample collected in September 1998 at a scent station on the Sweet Home Ranger District at elevation 4,200 feet was confirmed to be Canada lynx. While there have been observations of Canada lynx and lynx tracks nearer to the project site, none of these observations were confirmed. An unconfirmed observation of a lynx in the H.J. Andrews Experimental Forest approximately 6 miles north of Cougar Dam was recorded in August 1994. Lynx tracks were found but not confirmed in winter (March) in the Cougar Creek drainage near Castle Rock, approximately 2.5 miles northeast of Cougar Dam, and in the Penny Creek drainage, approximately 5.5 miles south of Cougar Dam, in 1994 and 1993, respectively.

5.8 PLANTS

5.8.1 Golden Paintbrush

Golden paintbrush was once common in the Willamette Valley in Linn, Marion, and Multnomah counties but is believed extirpated in Oregon (Eastman 1990; ONHP 1998). Plant surveys have been conducted extensively on project lands of the Willamette Valley, particularly at Fern Ridge. In 1985 and 1986, the Nature Conservancy, under contract to the USACE, undertook a survey of threatened and endangered plants at Fern Ridge Lake. Golden paintbrush has not been identified in surveys of suitable habitat on USACE project lands.

5.8.2 Howellia

The only known population of water howellia in either western Oregon or southwestern Washington is at Ridgefield National Wildlife Refuge in Washington. Four distinct colonies have been identified at the refuge, and range from approximately 10 to 15 feet in elevation

(Engler, personal communication, 2000). Three of these appear to be directly affected by the hydrology of the Columbia River, while the fourth is larger, slightly higher in elevation, perched, and more dependent upon rainwater and surface water runoff. This higher site is also associated with a dense stand of Oregon ash (Engler, personal communication, 2000; Gamon, personal communication, 2000). The three other sites have been subject to year around or late-season inundation over the past several years, which has influenced the abundance of plants (Engler, personal communication, 2000). Threats to this population at Ridgefield National Wildlife Refuge are changes in hydrology, encroachment by reed canarygrass, and destruction of aquatic and wetland vegetation by carp and nutria (Engler, personal communication, 2000; Gamon, personal communication, 2000).

All forested wetlands and backwater sloughs of the Willamette Basin and other Columbia Basin projects, particularly those nearest the valley floor could serve as potential habitat for water howellia. However, other than the population at Ridgefield National Wildlife Refuge, it is not known whether this species occurs on the USACE Willamette Basin projects, or on downstream lands that are directly or indirectly affected by the hydrology of the Willamette River. No surveys on USACE project lands have been directed toward locating this species. The ONHP has not conducted surveys exclusively for this species, but considers the species extirpated in Oregon (Vrilakas, personal communication, 2000).

5.8.3 Bradshaw's Desert Parsley

Bradshaw's desert parsley was once widespread in wet prairies of the Willamette and Umpqua valleys of Oregon; however, much of this habitat has been converted to agricultural lands or otherwise developed. It is now known to occur in only a few sites within Marion, Benton, Linn, and Lane Counties (ONHP 1998).

Fern Ridge is identified in the Recovery Plan (USFWS 1993) as one of the four recovery populations in the southwest valley area; along with West Eugene wetlands, the Long Tom Area of Area of Critical Environmental Concern (BLM, Eugene District), and Amazon Creek in South Eugene. An aggressive monitoring program at Fern Ridge has been undertaken to evaluate population status and trends for this and other rare plants in the prairie community.

USACE project lands at Fern Ridge support important populations of Bradshaw's desert parsley. Nine populations of Bradshaw's desert parsley are found along the east side of Fern Ridge Lake. Three distinct sub-populations are recognized within remnant wet prairie habitats in the Amazon-Dike 2, Royal Amazon, and Fisher Butte Management Units. The highest quality areas within these units have been designated as a Research Natural Area and are managed to maintain the prairie plant community, while allowing access for research. Management of the Research Natural Area includes periodic prescribed burning to retard the development of shrub-scrub and ash forest, and the eventual loss of grassland community.

In addition to the large, intact prairie populations at Fern Ridge, Bradshaw's desert parsley is also found in small patches consisting of two to several plants at Kirk Pond and Amazon-Dike 2 Management Units, and scattered along the impoundment dikes in the East and West Coyote Management Units. The role of these isolated plants in recovery and management of the species is not clear; accordingly, management efforts are focused on larger, intact prairie communities; individual plants found growing outside the communities are protected, but not given a high priority for management.

5.8.4 Nelson's Checker-Mallow

Suitable habitat for Nelson's checker-mallow may exist on Fern Ridge Lake project lands. However, despite considerable survey effort, this species is not known to occur on Fern Ridge or any other USACE project land in the Willamette Basin. The nearest known population is at Finley National Wildlife Refuge, greater than 15 miles north of Fern Ridge.

5.8.5 Willamette Daisy

Willamette daisy is documented on USACE project land in the East Coyote management unit at Fern Ridge. This unit is managed by the USACE (under license to the ODFW for a variety of wildlife values and for the protection of sensitive plants. Willamette daisy is also documented at Fisher Butte Research Natural Area, a site just south of Fern Ridge Reservoir. This are is under the jurisdiction of the BLM. Both locations have fairly dense populations of Willamette Daisy. A study by Oregon State University was initiated in 1993 to follow individual plants over time, looking at seedling recruitment and overall longevity of plants.

5.8.6 Kincaid's Lupine

Kincaid's lupine is listed by the ONHP as occurring within Linn, Lane, Benton, Douglas, Marion, Polk, and Yamhill Counties the Willamette Valley (ONHP 1998). The less than one tenth of 1 percent of historical Willamette Valley upland prairie remaining occurs in 84 remnant sites scattered throughout the Valley. Of these 84 sites, 80 percent are threatened by agricultural and forest practices, development, grazing, and road construction and maintenance.

Kincaid's lupine is found at several disjunct locations in the northeastern and eastern part of Fern Ridge Reservoir. The Fern Ridge subpopulation was assessed and mapped in 1998. Subpopulations and patches were located in the Amazon-Dike 2, Royal Amazon, and Fisher Butte management units. The principal populations are referred to as the Shore Lane, Spires, Eaton, and Green Oaks sites. Smaller populations are located within the Royal/Amazon and Fisher Butte management units.

The lupine at these sites are threatened to varying degrees by exotic shrubs (blackberry and Scotch broom) and competition from exotic grasses (especially tall oatgrass). These units are managed for wildlife and include areas designated as environmentally sensitive. The plants are counted annually for changes in populations. The encroachment of woody growth such as Scotch broom and Himalayan blackberry is also monitored. Management of these sites has included mowing the fields where lupine occurs in early June to discourage oatgrass (excluding the lupine patches), and then mowing the entire field, lupine included, in the late summer to control woody vegetation. The late summer mowing has produced visible results at most sites; blackberry and Scotch broom cover is reduced in comparison to sites not mowed. Hand-pulling broom has occurred at multiple sites since 1994, and is an on-going, annual management effort. Management of invasive shrubs and grasses is complicated by known or suspected presence of Fender's blue butterfly larvae at some sites, and hand cutting has been implemented at some locations to avoid negative effects of mowing or brush-hogging to the eggs and larvae of Fender's blue butterfly.

The Kincaid's lupine at Fern Ridge is part of a larger West Eugene complex that includes 3 sites. One is at Willow Creek (managed by the Nature Conservancy). Another is a small site near Fir Butte Road along the Amazon Canal, managed by the City of Eugene. The third is an experimental site north of Royal Avenue managed by the BLM. Other Willamette Valley sites include populations at Basket Butte, McDonald Forest, Coburg Ridge, and several smaller sites. The Willow Creek populations are the largest of the south valley sites, and support a much larger population of Fender's blue butterfly than do the Fern Ridge and Fir Butte sites. The extent of connectivity between the West Eugene sites is unknown; however, Hammond (1998) reports recolonization of a site from an approximate distance of 2 miles. The Fern Ridge lupine sites are generally within 0.5 - 1 mile from each other and at least 1 is within 2 miles from the next closest off-project site (Fir Butte). Barriers to migration between sites may be present and need to be evaluated.

Only 16 sites, including Fern Ridge, are in a protected management status, but biological factors and processes including succession, exotic species, and herbivory threaten these sites (63 FR 3863).